INSTRUCTION MANUAL

4004

DIGITAL MULTIMETER

RACAL-DANA

PUBLICATION NO. 980560

4004
DIGITAL MULTIMETER

RACAL-DANA

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RACAL

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FOR YOUR SAFETY

Before undertaking any maintenance procedure, whether it be a specific troubleshooting or maintenance procedure described herein or an exploratory procedure aimed at determining whether there has been a malfunction, read the applicable section of this manual and note carefully the WARNING and CAUTION notices contained therein.

The equipment described in this manual contains voltage hazardous to human life and safety and which is capable of inflicting personal injury. The cautionary and warning notes are included in this manual to alert operator and maintenance personnel to the electrical hazards and thus prevent personal injury and damage to equipment.

If this instrument is to be powered from the AC Mains through an autotransformer (such as a Variac or equivalent) ensure that the common connector is connected to the neutral (earthed pole) of the power supply.

Before operating the unit ensure that the protective conductor (green wire) is connected to the ground (earth) protective conductor of the power outlet. Do not defeat the protective feature of the third protective conductor in the power cord by using a two conductor extension cord or a three-prong/two-prong adapter.

Maintenance and calibration procedures contained in this manual sometimes call for operation of the unit with power applied and protective covers removed. Read the procedures carefully and heed Warnings to avoid "live" circuit points to ensure your personal safety.

Before operating this instrument.

1. Ensure that the instrument is configured to operate on the voltage available at the power source. See Installation section.
2. Ensure that the proper fuse is in place in the instrument for the power source on which the instrument is to be operated.
3. Ensure that all other devices connected to or in proximity to this instrument are properly grounded or connected to the protective third-wire earth ground.

If at any time the instrument:

- Fails to operate satisfactorily
- Shows visible damage
- Has been stored under unfavorable conditions
- Has sustained stress

It should not be used until the performance has been checked by qualified personnel.

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CONTENTS

Section		Page
CONTENTS.		
ILLUSTRATIONS		
1.	GENERAL INFORMATION	1-1
	1-1. INTRODUCTION.	1-1
	1-2. FEATURES.	1-1
	1-3. WARRANTY INFORMATION.	1-1
	1-4. CHANGE NOTICE	1-1
	1-5. OPTION 06 RECHARGEABLE BATTERY PACK (06)	1-1
	1-6. OPTION 51 DIGITAL INTERFACE	1-1
	1-7. OPTION 55T IEEE STANDARD 488 BUS INTERFACE	1-1
SPECIFICATIONS.		1-2
2.	INITIAL PREPARATION	2-1
	2-1. GENERAL	2-1
	2-2. INSPECTION.	2-1
	2-3. PREPARATION FOR USE	2-1
3.	OPERATING INSTRUCTIONS.	3-1
	3-1. GENERAL	3-1
	3-2. HOW TO SELECT POWER	3-1
	3-3. HOW TO SELECT FUNCTION.	3-2
	3-4. HOW TO SELECT RANGE	3-3
	3-5. HOW TO MEASURE VOLTAGE.	3-4
	3-6. HOW TO MEASURE CURRENT.	3-5
	3-7 HOW TO MEASURE RESISTANCE	3-6
	3-8. FURTHER MEASUREMENT CONSIDERATIONS.	3-7
	3-9. HOW TO USE MODEL 4004 DMM OFF-GROUND	3-10
	3-10. HOW TO USE THE OPTION 51 DIGITAL INTERFACE	3-11
	3-11. COMMENTS RELATIVE TO THE 4004 DMM SPECIFICATIONS	3-22
	3-12. OPTION 06 OPERATING TIPS	3-22
4.	ACCESSORIES.	4-1
	4-1. GENERAL	4-1
	4-2. POWER OPTIONS	4-1
	4-3. ISOLATED DIGITAL OUTPUT	4-1
	4-4. RACK MOUNTING	4-1
	4-5. MISCELLANEOUS	4-4
5.	THEORY OF OPERATION	5-1
	5-1. GENERAL	5-1
	5-2. OVERALL OPERATION	5-1
	5-3. INPUT SIGNAL CONDITIONING	5-1
	5-4. A/D CONVERTER AND DIGITAL CIRCUITS (SCHEMATIC 29145E, SHEET 2).	5-15
	5-5. DISPLAY BOARD, SCHEMATIC 27404D	5-21
	5-6. POWER SUPPLY, SCHEMATIC 29145E.	5-21
	5-7. OPTION 06 RECHARGEABLE BATTERY PACK, SCHEMATIC 26758C	5-23
	5-8. OPTION 51 DIGITAL INTERFACE	5-25

CONTENTS (CON'T)

Section		Page
6.	MAINTENANCE.	6-1
	6-1. GENERAL.	6-1
	6-2. REQUIRED TEST EQUIPMENT.	6-1
	6-3. PERFORMANCE VERIFICATION	6-1
	6-4. CALIBRATION REQUIREMENTS	6-7
	6-5. PREPARATION FOR CALIBRATION.	6-8
	6-6. CALIBRATION PROCEDURE.	6-9
	6-7. TROUBLESHOOTING AND REPAIR	6-15
	6-8. FUSE REPLACEMENT	6-21/22
7.	REPLACEABLE PARTS.	7-1
	7-1. GENERAL.	7-1
	7-2. ORDERING INFORMATION	7-1
	7-3. FACTORY SERVICE.	7-1
	7-4. REPLACEABLE PARTS LIST	7-1
	7-5. CROSS REFERENCE OF MANUFACTURERS	7-2
	7-6. COVERS AND PANELS.	7-2
	7-7. COMPONENT DESIGNATIONS FOR PC-446.	7-2
	7-8. SCHEMATICS	7-2
	7-9. COMPONENT LAYOUTS.	7-2
	7-10. SPARE PARTS KIT.	7-5

ILLUSTRATIONS

FIGURE NO.	TITLE	PAGE
1-1	Model 4004 Front Panel	1-3
1-2	Bottom View Showing Line Cord.	1-4
1-3	Tilt Bail Positions.	1-5
1-4	Dimensional Data	1-6
2-1	Rear Panel Showing Current Fuse.	2-2
2-2	Option 06 Rechargeable Battery Pack	2-4
2-3	Installation of Battery Pack	2-5
3-1	Front Panel Pushbutton Selection	3-3
3-2	Typical Model 4004 Current Display (ACmA).	3-5
3-3	Typical 2 WIRE Resistance Measurement.	3-6
3-4	Typical 4 WIRE Resistance Measurement.	3-8
3-5	Semiconductor Diode and Transistor Testing	3-9
3-6	Use of Multimeter Off Ground	3-10
3-7	Option 51 Digital Output Interface.	3-12
3-8	Installation of Option 51	3-13
3-9	Connector Pin Identification For P1006 and P1101	3-15
3-10	Card-Edge Connectors	3-15
3-11	Location of Jumpers and Pull-Ups on Option 51	3-16
4-1	Option 60 Single Rack Mounting Kit.	4-2
4-2	Option 65 Dual Rack Mounting Kit	4-4
5-1	Overall Block Diagram of Model 4004	5-2
5-2	Simplified Block Diagram of Signal Conditioning Circuits	5-2
5-3	Simplified Schematic of DC Attenuator.	5-6
5-4	Simplified Schematic of AC/DC Converter.	5-7
5-5	Simplified Schematic of 4004 I/V Converter	5-8
5-6	Simplified Ohms Converter, Two-Wire Ohms Configuration	5-10
5-7	Four-Wire Ohms Measuring Technique	5-10
5-8	Simplified Schematic of Clamp.	5-12
5-9	Simplified Schematic of Active Filter.	5-12
5-10	Simplified Block Diagram of A/D Converter.	5-14
5-11	A/D Converter System Timing	5-15
5-12	Simplified Schematic of A/D Buffer	5-16
5-13	Simplified Schematic of the A/D Converter.	5-17
5-14	Simplified Schematic of 669 kHz Oscillator	5-19
5-15	Simplified Schematic of Reference Supply	5-20
5-16	Digital Display Multiplex Scheme	5-22
5-17	Option 51 Block Diagram	5-24
6-1	Location of Calibration Adjustments.	6-10
6-2	Location of Connectors and Test Points	6-14
7-1	Top and Bottom Cover Assembly	7-3

SECTION 1. GENERAL INFORMATION.

1-1. INTRODUCTION. The Model 4004 Digital Multimeter is a wide-range, general-purpose measuring instrument, capable of measuring ac/dc voltage, ac/dc current and resistance. (See Table 1-1 for Specifications, Page 1-2).

1-2. FEATURES.

a. Automatic Ranging and Polarity.

b. Manual Range Selection and Range Hold.

c. HI and LO Ohms Capability.

d. Line Operation.

e. Optional Battery Operation, Option 06

f. Floating Capability to ±1400V peak.

g. Optional Isolated Digital Interface, Option 51 and 55T.

1-3. WARRANTY INFORMATION. The warranty is stated in the front material of the manual. If there is a need for service, contact your Racal-Dana representative or authorized repair facility as given in our catalog.

1-4. CHANGE NOTICE. Improvements or changes to the instrument not incorporated into the manual will be explained on an addendum sheet attached to the inside back cover of the manual.

1-5. OPTION 06 RECHARGEABLE BATTERY PACK. The Option 06 is an accessory battery pack which enables either line or battery operation. The Option 06 has built-in recharging circuitry. The Option 06 is field-installed on the Model 4004 DMM

1-6. OPTION 51 DIGITAL INTERFACE. The Option 51 is a field-installable digital output option. It provides isolated open-collector BCD outputs and control lines.

1-7. OPTION 55T IEEE STANDARD 488 BUS INTERFACE. The Option 55T is a field-installable digital interface option that provides logic and control functions necessary to make the Model 4004 bus compatible in accordance with the IEEE Standard 488-1975. Refer to the Instruction Manual for Option 55T for operation and service instructions for this option.

IMPORTANT

The ⚠ Symbol can be found in various places in this Instruction Manual. Carefully read the associated *CAUTION* statements with regard to proper use and handling of the instrument. Damage to the instrument may occur if these precautions are ignored.

The ↯ symbol can be found in various places in this Instruction Manual. This symbol indicates those areas on the instrument which are potential shock hazards. Carefully read the associated *WARNING* statements with regard to proper use and handling of the instrument. Serious personal injury may result if these precautions are ignored.

TABLE 1-1.
SPECIFICATIONS

As an Auto/Manual Ranging DC Voltmeter

RANGE	MAXIMUM READING	ACCURACY [± (% of rdg + digits)] · (24h, 25° ± 1°C)	(6 months, 20°-30°C)	(1 year, 20°-30°C)	TEMPERATURE COEFFICENT (0°-20°C and 30°-55°C) ± (% of rdg + digits)/°C	INPUT RESISTANCE	MAX. ALLOWABLE INPUT
300mV	299 99	0 009% + 1d	0.013% + 1d	0 015% + 1d	0.0010% + 0 1d	>1000MΩ	1200V peak*
3 V	2 9999	0 006% + 1d	0 013% + 1d	0.015% + 1d	0 0010% + 0 1d	>1000MΩ	1200V peak*
30 V	29.999	0.009% + 1d	0 013% + 1d	0 015% + 1d	0 0015% + 0.1d	0MΩ	1200V peak
300 V	299 99	0.009% + 1d	0.013% + 1d	0.015% + 1d	0.0015% + 0.1d	10MΩ	1200V peak
1200 V	1200.0	0.009% + 1d	0 013% + 1d	0.015% + 1d	0.0035% + 0.1d	10MΩ	1200V peak

NOTE. rdg means reading.

*Overload on manual range not to exceed 600 volts continuous or 1200V for 3 seconds.

NORMAL MODE REJECTION RATIO: Greater than 80dB over 1 digit at 50 and 60Hz, 70dB 50Hz to 10kHz.

COMMON MODE REJECTION RATIO (1kΩ unbalance): Greater than 120dB at dc and 50Hz to 10kHz.

ON RANGE RESPONSE TIME: Less than 0.8 second to within 0.1% of final reading.

As an Auto/Manual Ranging AC Voltmeter

RANGE	MAXIMUM READING	Accuracy (0.3% to 100% of Range: 1 year, 20°-30°C) ±(% of rdg + digits) (50Hz to 20kHz)	(20Hz to 50Hz & 20kHz to 100kHz)	TEMPERATURE COEFFICENT (0°-20°C & 30°-55°C) ± (% of rdg + digits)/°C (50Hz to 20kHz)	(20Hz to 50Hz & 20kHz to 100kHz)
300mV	299 99	0 20% + 6d***	1 0% + 20d	015% + 0 5d	0 05% + 0 5d
3 V	2 9999	0 20% + 6d	1.0% + 20d	015% + 0 5d	0 05% + 0 5d
30 V	29 999	0 20% + 6d	1.0% + 20d	015% + 0 5d	0 05% + 0 5d
300 V	299 99	0.20% + 6d	1 0% + 20d	015% + 0 5d	0 05% + 0 5d
1000 V	1000 0	0 25% + 6d*	1.0% + 20d**	020% + 0 5d*	0 05% + 0 5d**

Average responding calibrated in rms of a sine wave.

* 50Hz - 10kHz.
** 20Hz-50Hz & 10kHz-20kHz
***With input shorted, display reads approximately 0.2 mV.

MAXIMUM ALLOWABLE INPUT: 1000V rms sine or dc, 2 X 10^7V•Hz

ON RANGE RESPONSE TIME: Less than 1.3 second to within 0.05% of final reading.

COMMON MODE REJECTION RATIO (1kΩ unbalance, Lo driven): Greater than 100dB at dc and 50 to 60Hz. decreasing to 70dB at 10kHz.

INPUT IMPEDANCE: 2 megohms shunted by less than 50 picofarads

As an Auto/Manual Ranging Ohmmeter

RANGE	MAXIMUM READING	ACCURACY (1 year, 20°-30°C) ± (% of rdg + digits) HI - mode - LO		MAXIMUM VOLTAGE ACROSS UNKNOWN ON RANGE* HI - mode	LO	ALLOWABLE 4-TERMINAL LEAD RESISTANCE	TEMPERATURE COEFFICIENT (0°-20°C and 30°-55°C) ± (% of rdg + digits)/°C HI - mode - LO	
300 Ω	299 99	—	0 035% + 1d	--	0 3V	10Ω	—	0 003% + 0 1d
3kΩ	2 9999	0 035% + 1d	0 035% + 1d	3V	0 3V	100Ω	0 003% + 0 1d	0 003% + 0 1d
30kΩ	29 999	0 035% + 1d	0 035% + 1d	3V	0 3V	100Ω	0 003% + 0 1d	0.003% + 0 1d
300kΩ	299 99	0 035% + 1d	0 045% + 1d	3V	0.3V	100Ω	0 003% + 0.1d	0 004% + 0 1d
3MΩ	2.9999	0 05% + 1d	0 15% + 1d	3V	0 3V	100Ω	0.004% + 0 1d	0 02% + 0 1d
30MΩ	29 999	0 18% + 1d	0.8 % + 1d	3V	0 3V	100Ω	0 02 % + 0 1d	0 15% + 0 1d
300MΩ	299 99	1 5 % + 1d	-	3V	—	100Ω	0 15 % + 0 1d	—

*Maximum open-circuit voltage, 5 volts.

CONFIGURATION: 4-terminal or 2-terminal, switch selected.

MAXIMUM ALLOWABLE INPUT: 360V peak, 250V rms or dc

ON RANGE RESPONSE TIME: Hi ohms below 10MΩ: less than 0.9 second to within 0.01% of final reading. 10MΩ to 100MΩ and Lo ohms: less than 2.2 seconds to within 0.01% of final reading.

As an Auto/Manual Ranging AC and DC Ammeter

RANGE	MAXIMUM READING	DC ACCURACY (1 year, 20°-30°C) ± (% of rdg + digits)	AC ACCURACY (1 year, 20°-30°C) 50Hz-5kHz ± (% of rdg + digits)	INPUT RESISTANCE	FUSE PROTECTION
300μA	299 99	0 1% + 2d	0 3% + 18d	1kΩ	3A, 250V
3mA	2 9999	0 1% + 2d	0.3% + 18d	100 Ω	3A, 250V
30mA	29 999	0.1% + 2d	0.3% + 18d	10 Ω	3A, 250V
300mA	299 99	0 1% + 2d	0.3% + 18d	1 3 Ω	3A, 250V
3 A*	2.9999	0.1% + 2d	0 3% + 18d	0 4 Ω	3A 250V

*Self-heating effects of currents greater than 1 ampere can double % of reading accuracy.

TEMPERATURE COEFFICIENT (0°-20°C and 30°-55°C):
DC: ±(0.005 % of reading + 0.2 digits /°C.
AC: ± (0.03% of reading + 1 digit)/°C.

ON RANGE RESPONSE TIME:
DC. less than 0.8 second to within 0.01% of final reading.
AC: less than 1.3 second to within 0.05% of final reading.

GENERAL

ZERO STABILITY: Autozeroed to within accuracy specifications, 0°C-55°C.
DISPLAY: Five .43 inch LED digits, appropriate decimal position, function and polarity indication.
CONVERSION PERIOD: 320 milliseconds.
ISOLATION: Input LO to power line ground, greater than 1000 megohms shunted by approximately 300 picofarads. Maximum input between LO and power line ground, 1400 volts peak
POLARITY: Automatic, minus indicated, plus implied.
RANGING: Automatic or manual. Upranges at 30000, downranges at 2599
OVERLOAD INDICATION: Blinks at and above ±1200V dc, 1000V ac. Blanks last four digits above 29999 counts on all other ranges.

SELF TEST: Allows self-test of functional operation on 30 volt ac and dc ranges, 30kΩ ranges and 3mA ac and dc ranges.
WARMUP: 1 hour to rated accuracy
ENVIRONMENTAL LIMITS (without batteries installed):
Operating: 0°C to 55°C. 0% to 80% relative humidity up to 35°C.
Storage: -25°C to + 65°C.
POWER: 105 - 125 or 210 - 250 volts (switch selected), 50Hz - 60Hz; 20VA. 90 - 110 volts available Optional rechargeable battery pack
CONNECTORS: Input: Banana jacks
DIMENSIONS, WEIGHT: 85mm high x 235mm wide x 275mm deep (3½ in. x 9¼ in. x 10¾ in.) Net weight, exclusive of batteries, 2.3 kg (5 lbs.)

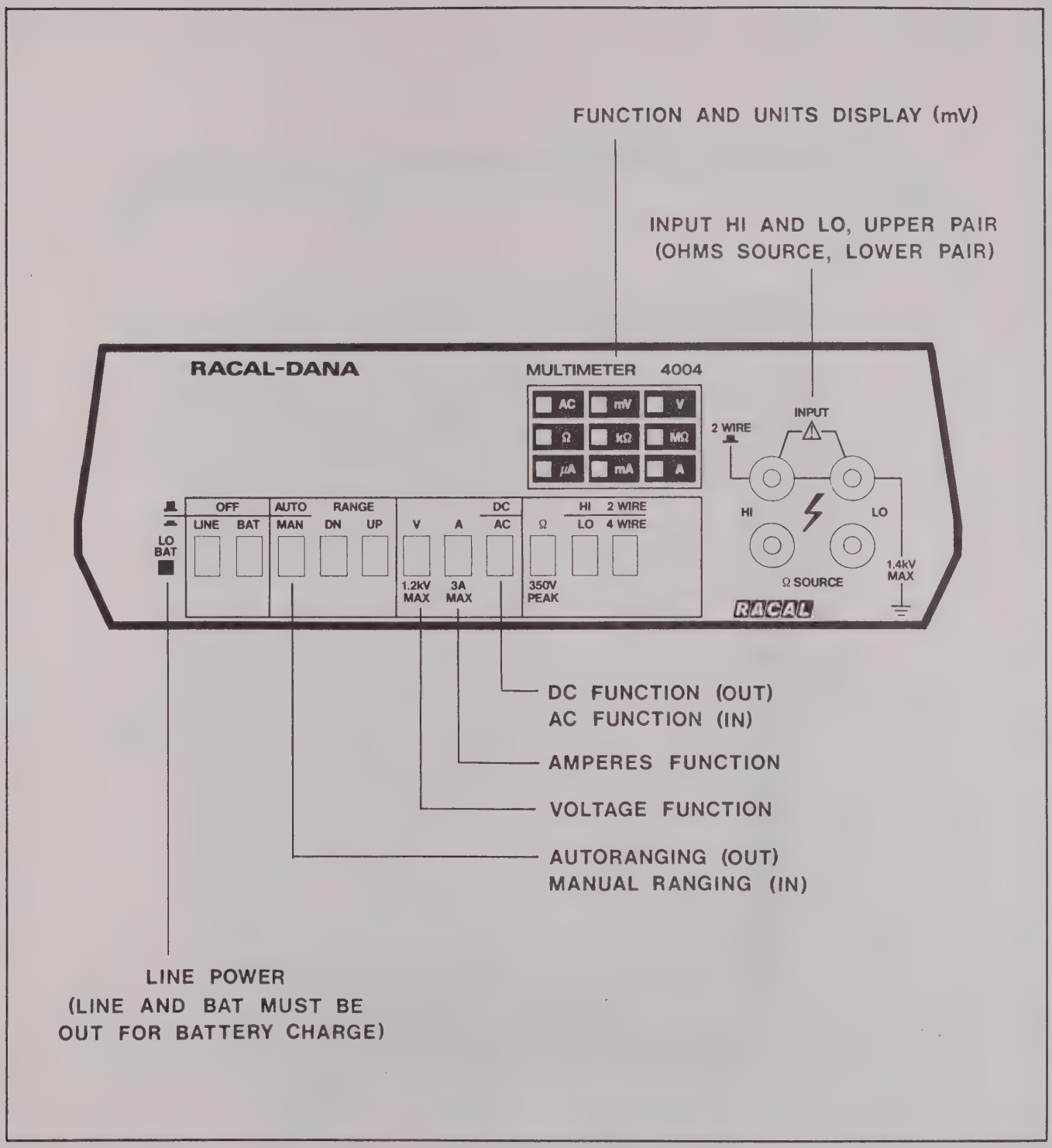


FIGURE 1-1. Model 4004 Front Panel.

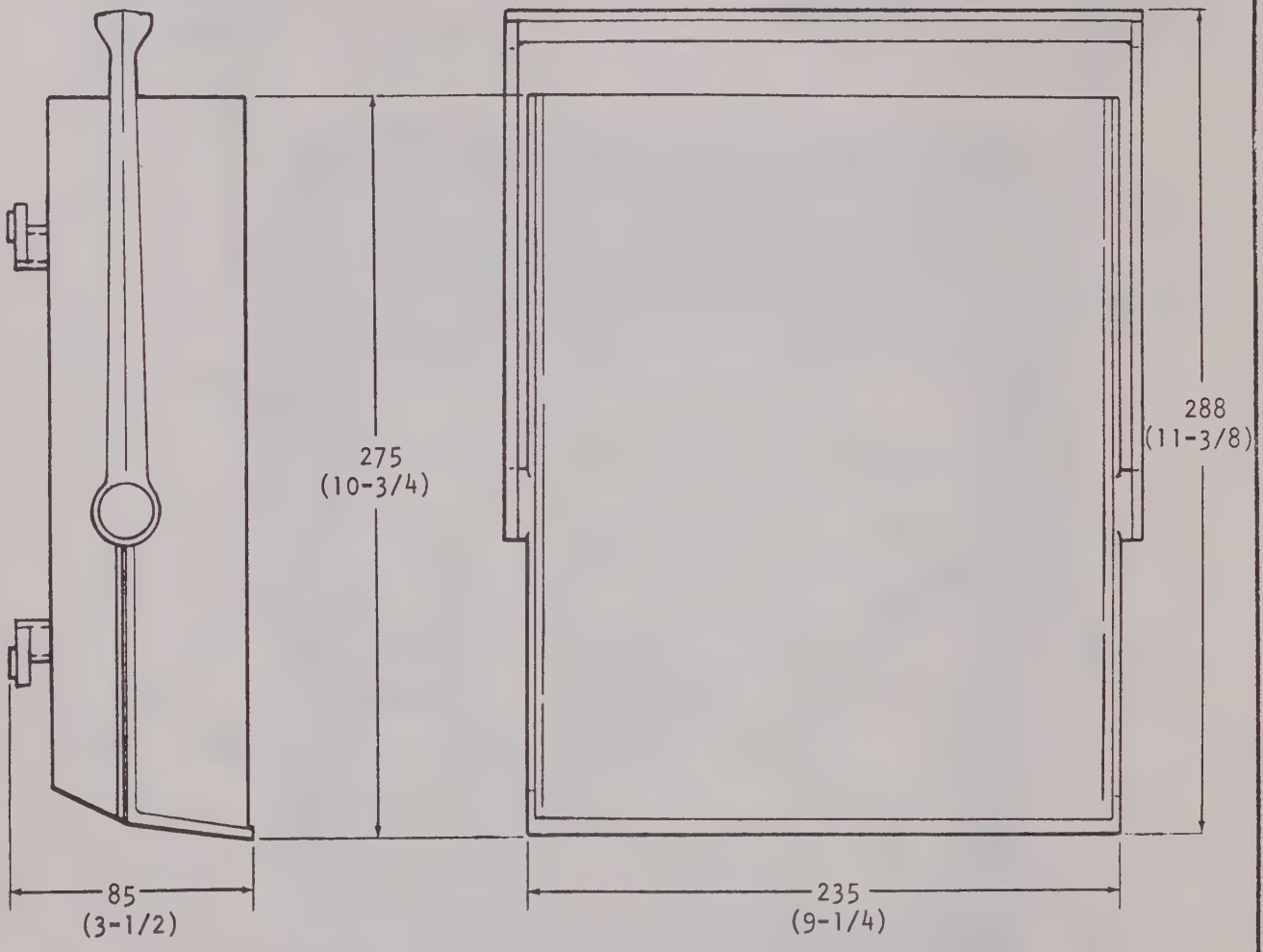


FIGURE 1-4. Dimensional Data

SECTION 2. INITIAL PREPARATION.

2-1. GENERAL. This section provides information needed for incoming inspection and preparation for use.

2-2. INSPECTION. The Model 4004 DMM was carefully inspected both mechanically and electrically before shipment. Upon receiving the instrument, check for any obvious damages which may have occurred during transit. Report any damages to the shipping agent. To verify the electrical specifications, follow the procedures given in Section 6.

2-3. PREPARATION FOR USE. The Model 4004 DMM is shipped ready-to-use. The instrument can be powered from line voltage or from rechargeable nickel-cadmium batteries (when the Option 06 Rechargeable Battery Pack is installed).

a. Line Power. The Model 4004 DMM has an attached three-wire line cord which mates with third-wire grounded receptacles (NEMA 5-15P). The permanently installed line cord is stored by wrapping the cord around the base of the instrument as shown in Figure 1.2.

CAUTION

⚠ This instrument has an internal line power selector switch that must be set to 234V position for operation above 125 volts rms, 50-60 Hz.

1. How to set the Internal Line Voltage Switch (S601). The Model 4004 DMM has a two position slide switch located on the main circuit board. For operation above 125 volts, the switch setting and fuse must be changed. The top cover must be removed to gain access to the circuit board as described in MAINTENANCE section.

WARNING

Disconnect the line cord before removing the top cover of the instrument. Line voltage is present at various points on the circuit board and represents a SHOCK HAZARD.

NOTE

Optional line voltage range is available when wiring modifications are made to transformer T601 as shown on schematic 29145E.

TABLE 2-1.
Summary of Standard and Optional Line Voltages.

Standard	Optional
105 to 125 V rms 210 to 250 V rms	90 - 105 V rms - Transformer wiring must be modified.

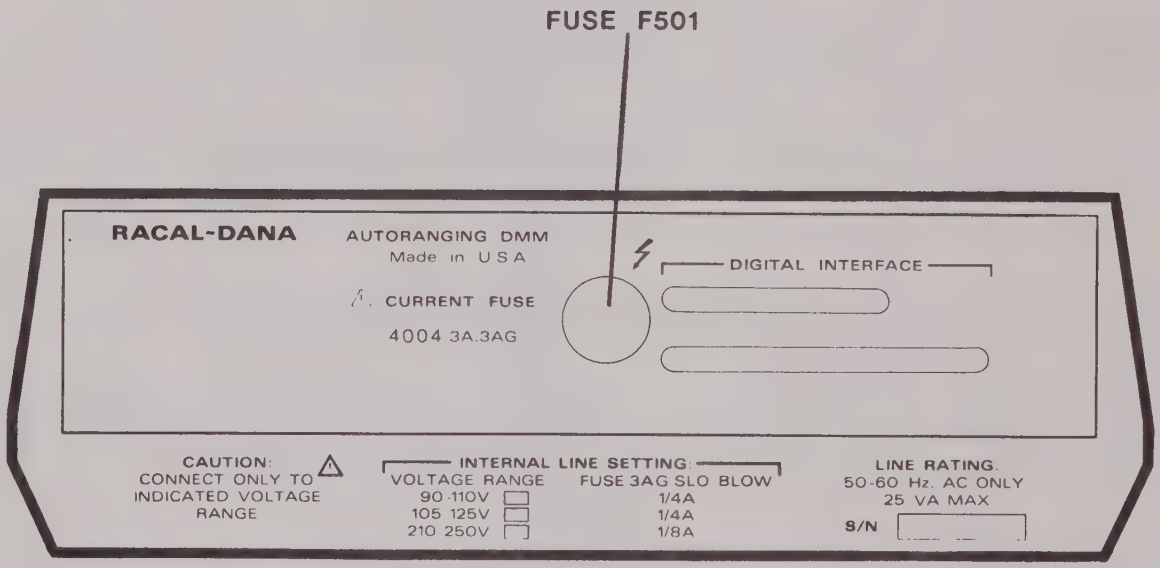


FIGURE 2-1. Rear Panel Showing Current Fuse.

2. Line Fuse Requirement. The Model 4004 DMM uses a single line fuse to protect the line-operated power supply. The fuse is a 3 AB or 3 AG, slow-blow type. Replace with 1/4 ampere for 117 volts operation or 1/8 ampere for 234 volts.

IMPORTANT

⚠ Replace fuse with correct rating, otherwise, damage to the instrument could result.

3. How to Replace the Line Fuse. The fuse is installed on the main circuit board as shown in Figure 6-2 (Page 6-14). The top cover must be removed to gain access to the circuit board as described in Section 6. Use Racal-Dana FU-17 (1/4A) for 117V; FU-20 (1/8A) for 234V.

WARNING

Disconnect the line cord before removing the top cover of the instrument. Line voltage is present at various points on the circuit board and represent a SHOCK HAZARD.

CAUTION

⚠ The fuse installed on the rear panel of the Model 4004 DMM is used only for current range protection. This fuse is not a line voltage protection fuse.

b. Battery Power. To operate the Model 4004 DMM from batteries, the Option 06 Rechargeable Battery Pack must be installed. The Option 06 can be either field or factory-installed (at the time the Model 4004 DMM is purchased).

NOTE

The Option 06 Rechargeable Battery Pack can be installed by the user within the Model 4004 DMM at any time. However, if the Option 51 Digital Output is already installed, the Option 06 cannot be used simultaneously.

1. How to Install the Option 06 Rechargeable Battery Pack. The batteries furnished with the Option 06 are already installed in the battery pack. The battery pack includes 7 rechargeable "C" cells (1.2V, 2 AMP Hr) and two 19.2 volt packs (sixteen 1.2V-cells per pack). See Figure 2-3.

a) Check the fuses on the Battery Pack. Three fuses are used. All are 1 ampere, 3AB or 3 AG, Slo-Blo types, Racal-Dana Part No. FU-10.

b) Check for proper installation of batteries in the Battery Pack. If replacement battery cells are to be installed, be certain to observe the proper polarity of the individual cells as shown in Figure 2-3.

c) To install the Battery Pack, turn the instrument over so that the bottom cover faces up. Loosen four slotted screws on the bottom cover. The screws are captive, that is they cannot be removed completely. Turn over the instrument with the top cover facing up, taking care to hold the top and bottom covers together. Carefully, remove the top cover to gain access to the printed circuit board. There is a connection between the top cover and the main circuit board which must be temporarily removed in order to free the top cover. Check to see that the four insulating spacers are in position on the circuit board as shown in Figure 2-3. Plug the two 5-wire connectors (J401, J402) into the mating receptacles (P401, P402) taking care to orient the connectors as shown. Place the Option 06 in position on the spacers with the pack oriented as shown in Figure 2-3. Replace the connector from the top cover to the circuit board. Replace the top cover. Turn over the instrument with the bottom cover facing up and tighten down the four slotted-head screws.

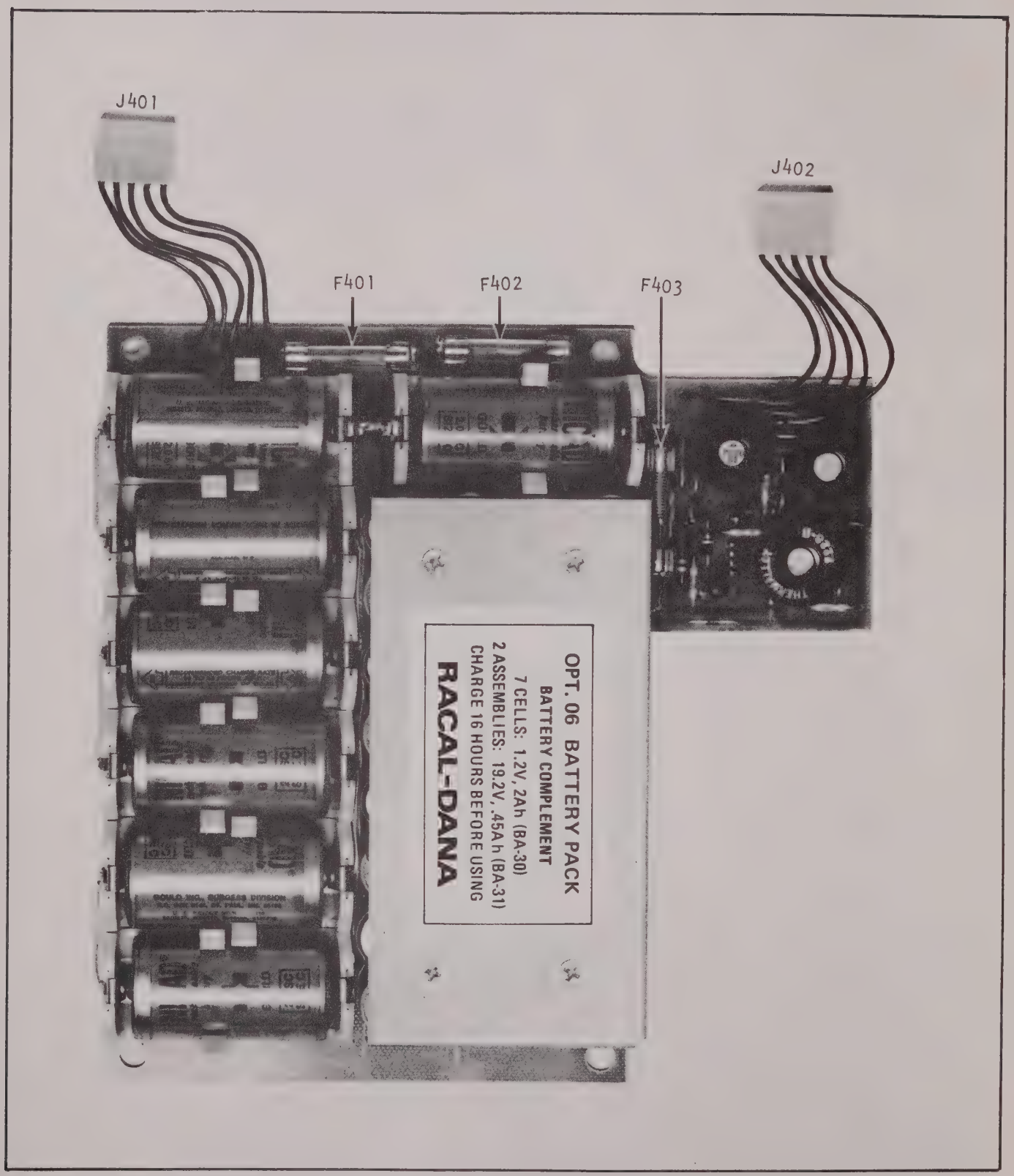


FIGURE 2-2. Option 06 Rechargeable Battery Pack.

WARNING

Disconnect the line cord on the instrument before the Battery Pack is installed. Line voltage is present at various places on the circuit board and is a SHOCK HAZARD.

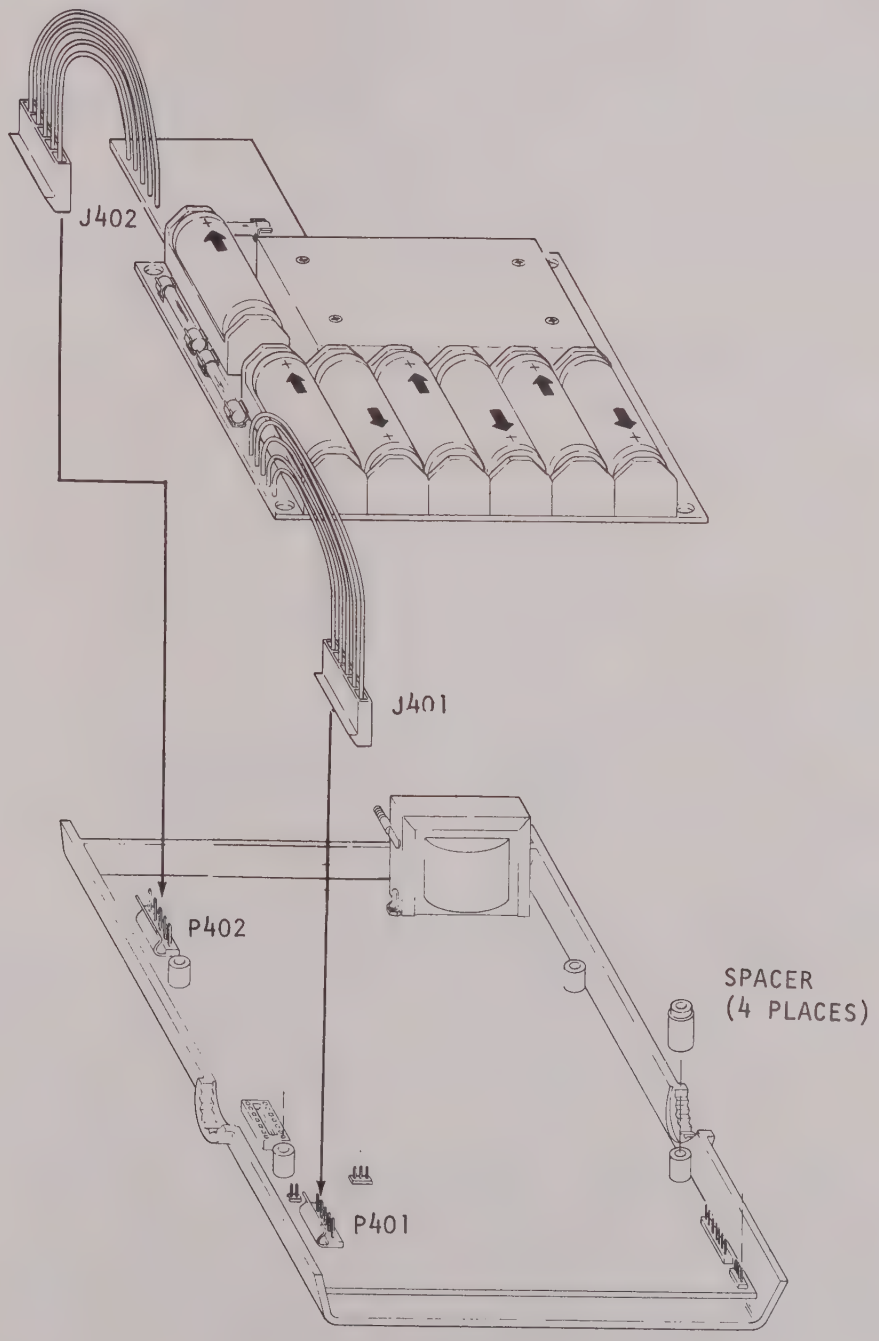


FIGURE 2-3. Installation of Battery Pack.

TABLE 2-2.
Summary of Batteries Used in the Option 06

Description	Quantity	Voltage	Racal-Dana Part No.
1.2V "C" cell (2 AMP-HR)	7	8.4V	BA-30
+19.2V pack (16-1.2V cells)	1	+19.2V	BA-31
-19.2V pack (16-1.2V cells)	1	-19.2V	BA-31

CAUTION

⚠ The Option 06 is shipped from the factory in an uncharged condition. Therefore, the pack should be installed in the Model 4004 DMM and charged prior to use.

2. How to Check Batteries.

a) The Model 4004 DMM has a built-in LO BAT indicator to permit easy determination of battery condition. The Model 4004 DMM also has an individual test point on the bottom panel usually needed only for troubleshooting purposes (See Figure 1-2).

b) The LO BAT indicator will be lighted when the Battery Pack goes below normal operating voltage. When the indicator turns on, the Model 4004 DMM should be switched to LINE or OFF to permit recharging of the Pack.

c) The test point may be checked at any time using the Model 4004 DMM or other measuring instruments. The voltages are summarized in Table 2-3.

IMPORTANT

The instrument must be operated in BAT mode in order to obtain a valid battery condition at test point "A". This will ensure that the batteries are supplying power to the instrument. If the voltage is measured when the Model 4004 DMM is operated in the LINE mode, a different reading may be observed since the batteries are being charged.

TABLE 2-3.
Summary of Battery Voltage Levels (BAT mode)

Test Point	Acceptable Battery Levels Range	Normal	Recharge If Below	Battery Tested
"A"	19V → +20.5V	+19.2	19V	BT402

3. How to Charge the Batteries. The Option 06 provides built-in recharging circuitry. The Model 4004 DMM must be connected to line voltage. Recharging occurs at the most rapid rate when the Model 4004 DMM is set to OFF. Typically, the recharge time is 2.5 hours per hour of discharge. After the batteries have been fully charged, either turn the instrument on with the LINE switch (trickle charge condition) or disconnect the line cord to prevent overcharging of the batteries.

CAUTION

⚠ Overcharging the batteries will raise the internal temperature of the battery pack and may shorten the life of the batteries.

SECTION 3. OPERATING INSTRUCTIONS

3-1. GENERAL. This section provides information needed to operate the Model 4004 DMM for measurement of voltage, current and resistance.

3-2. HOW TO SELECT POWER. The Model 4004 DMM may be powered from line voltage or rechargeable nickel-cadmium batteries (when the Option 06 is installed). The Model 4004 DMM has a built-in line-voltage power supply and power cord.

NOTE

The Option 06 Rechargeable Battery Pack may be ordered at the time of purchase of the Model 4004 DMM or may be purchased and field-installed at a later time if so desired. The Option 06 features plug-in wiring and, as a result, no modifications need to be made to the Model 4004 DMM chassis.

a. How to Operate from Line Power. The Model 4004 DMM can be powered from line voltage over four ranges from a minimum of 90 V rms to a maximum of 250 V rms. Table 3-1 summarizes the line voltages permitted.

1. Set the internal line voltage switch to either 117V or 234V.
2. Plug the line cord into source of line power.
3. Depress LINE pushbutton.

NOTE

Power on will be indicated by a lighted display with one or more digits and measurement unit showing.

TABLE 3-1.
How to Set Line Voltage

Range Desired	Switch S001	Transformer Modification*
90-105V	117V	Yes *
105-125V	117V	No
210-250V	234V	No

*For this range, the leads must be rewired. See Schematic 29145E Sheet 3.

b. How to Operate from Battery Power.

1. Install the Option 06 Rechargeable Battery Pack. (See Section 2, page 2-3.)
2. Depress BAT pushbutton.
3. If LO BAT indicator is lighted, the battery pack must be charged a minimum of 16 hours to provide fully charged operation of the Model 4004 DMM.

NOTE

To charge the Option 06, release both LINE and BAT pushbuttons and connect the line cord to line power. If it is desired to use the Model 4004 DMM immediately, depress LINE. The Model 4004 DMM will be useable for measurements although the battery charging rate is decreased considerably.

4. If the LO BAT indicator is not lighted in BAT mode, the model 4004 DMM may be used for measurements.

NOTE

The Option 06 is shipped from the factory in uncharged condition. Therefore the Option 06 should be installed and charged prior to use. After the Option 06 has been charged for at least 16 hours, the Model 4004 DMM can be powered continuously for at least 6 hours.

TABLE 3-2.
Summary of Operation in LINE and BAT Modes

Button Depressed	Condition of Instrument		
	Line Power Connected 06 not installed	Line Power Connected 06 installed	Line Power Not Connected 06 installed
LINE	ON	ON Battery trickle charged.	OFF
BAT	OFF	ON Battery slowly discharged.	ON
NEITHER LINE NOR BAT	OFF	OFF Battery charged at maximum rate.	OFF

3-3. HOW TO SELECT FUNCTION. Function is selected by means of four pushbuttons: DC/AC, V, A and Ω.

a. V. This pushbutton must be used with DC/AC to select either DC voltage or AC Voltage.

1. DC Voltage. Depress V. Release DC/AC.
2. AC Voltage. Depress V. Depress DC/AC.

b. A. This pushbutton must be used with DC/AC to select either DC current or AC current.

1. DC Current. Depress A. Release DC/AC.
2. AC Current. Depress A. Depress DC/AC.

c. DC/AC. This pushbutton selects whether the selected voltage or current function will be AC or DC. When depressed, AC is selected.

d. Ω. Depress Ω to measure resistance.

NOTE

V, A, and Ω pushbuttons are interlocked so that only one pushbutton is depressed at a time. However, it is possible to have all pushbuttons out which disconnects the input HI and LO terminals and no measurement can be made. (The volts or millivolts indicator will be lighted in this instance.) Ω overrides DC/AC. V or A overrides HI/LO and 2 WIRE/4 WIRE.

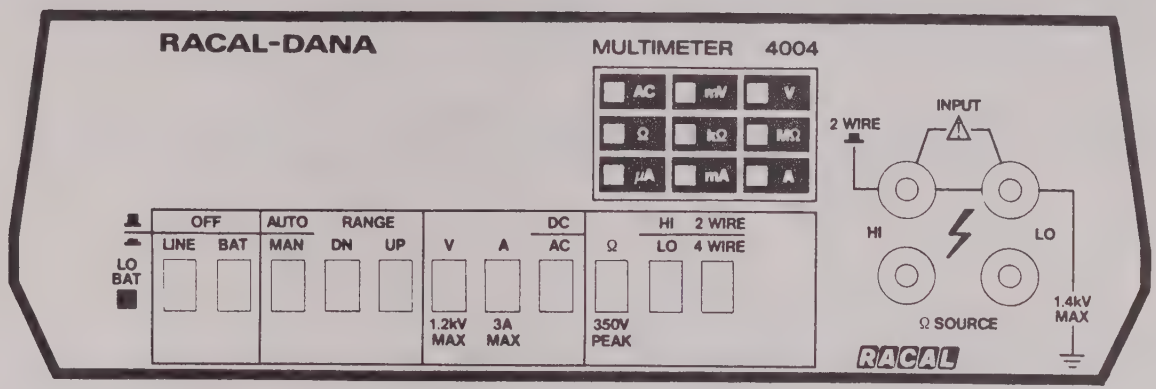


FIGURE 3-1. Front Panel Pushbutton Selection.

3-4. HOW TO SELECT RANGE. The Model 4004 DMM provides automatic or manual ranging. The AUTO/MAN pushbutton determines the ranging mode, where AUTO = fully automatic ranging.

a. AUTO. When released, the Model 4004 DMM automatically selects the appropriate range in accord with the following rules.

1. When the display exceeds 29999 the Model 4004 DMM upranges (that is, it changes to less sensitivity and the decimal point moves appropriately).

2. When the display reaches 02599 the Model 4004 DMM downranges (that is, it changes to greater sensitivity and the decimal point moves appropriately).

b. MAN. When depressed, the range is placed to hold. The user can cause the Model 4004 DMM to uprange or downrange by using the UP RANGE and DN RANGE pushbuttons.

1. When DN RANGE is momentarily depressed, the Model 4004 DMM will downrange one decade of sensitivity. Each time the pushbutton is depressed and released, one downrange will occur until most sensitive range is obtained.

2. When UP RANGE is momentarily depressed, the Model 4004 DMM will uprange one decade of sensitivity. Each time the pushbutton is depressed and released, one uprange will occur until least sensitive range is obtained.

3-5. HOW TO MEASURE VOLTAGE. The Model 4004 DMM measures ac and dc voltage in five ranges: 0.3V, 3V, 30V, 300V and 1200V DC (1000VAC).

CAUTION

⚠ Maximum input voltage depends on the range selected. Table 3-3 gives the maximum allowable continous input for each range on AC and DC. Do not exceed these voltages or damage to the instrument will occur.

TABLE 3-3.
Maximum Allowable Continuous Input

Range	AC Voltage (ACV)	DC Voltage (DCV)
0.3V	1000V rms	1200V peak*
3 V	1000V rms	1200V peak*
30 V	1000V rms	1200V peak
300 V	1000V rms	1200V peak
1000 V	1000V rms	1200V peak

*Overload on manual range not to exceed 600 volts continuous or 1200V for 3 seconds.

a. DC Voltage. The Model 4004 DMM detects dc voltages from ±10 microvolts/digit to ±1200 volts (1200.0 display). The maximum display is 29999. When the display exceeds 29999, a 3 remains lighted, but all other digits are blanked. The display blinks above 1199.9 volts on the highest range.

1. Set to DC Volts.

2. Set to AUTO.

3. Connect the Signal to be measured between HI and LO terminals. (The terminals are designed to accept banana style plugs.

4. Observe the displayed digits, polarity sign, decimal point location, and measurement unit (mV or V). If no polarity sign is indicated, a positive polarity is implied.

b. AC Voltage. The Model 4004 DMM detects ac voltages from 10 microvolts rms to 1000 volts (1000.0 display). The maximum display is 29999. When the display exceeds 29999, a 3 remains lighted, but all other digits are blanked. The display blinks above 999.9 volts on the highest range.

1. Set to AC Volts. (The AC indicator should be lighted.)

2. Set to AUTO.

3. Connect the signals to be measured between HI and LO terminals. (The terminals are designed to accept banana style plugs.

4. Observe the displayed digits, decimal point location, and measurement unit (mV or V).

3-6. HOW TO MEASURE CURRENT. The Model 4004 measures ac and dc current in five ranges: 0.3mA, 3mA, 30mA, 0.3A, and 3A.

CAUTION

⚠ The Model 4004 DMM is protected by a 3 ampere fuse on all ranges. If the fuse is blown, a replacement Racal-Dana Part No. FU-2 should be installed in the rear panel fuse holder. (See Figure 2-1).

a. DC Current. The Model 4004 DMM detects dc currents from ±10 nanoamperes to ±3 amperes. The maximum display is 29999. When the display exceeds 29999, a 3 remains lighted, but all other digits are blanked.

1. Set to DC Amperes.
2. Set to AUTO.
3. Connect the signal to be measured at the HI terminal.
4. Observe the displayed digits, polarity sign, decimal point location, and measurement unit (μA, mA, or A). If no polarity sign is indicated, a positive polarity is implied.

b. AC Current. The Model 4004 DMM detects ac currents from 10 nanoamperes rms/digit to 3 amperes rms. The maximum display is 29999. When the display exceeds 29999, a 3 remains lighted, but all other digits are blanked.

1. Set to AC Amperes. (The AC indicator should be lighted.)
2. Set to AUTO.
3. Connect the signal to be measured at the HI terminal.
4. Observe the displayed digits, decimal point location, and measurement unit (AC μA, AC ma, or AC A).

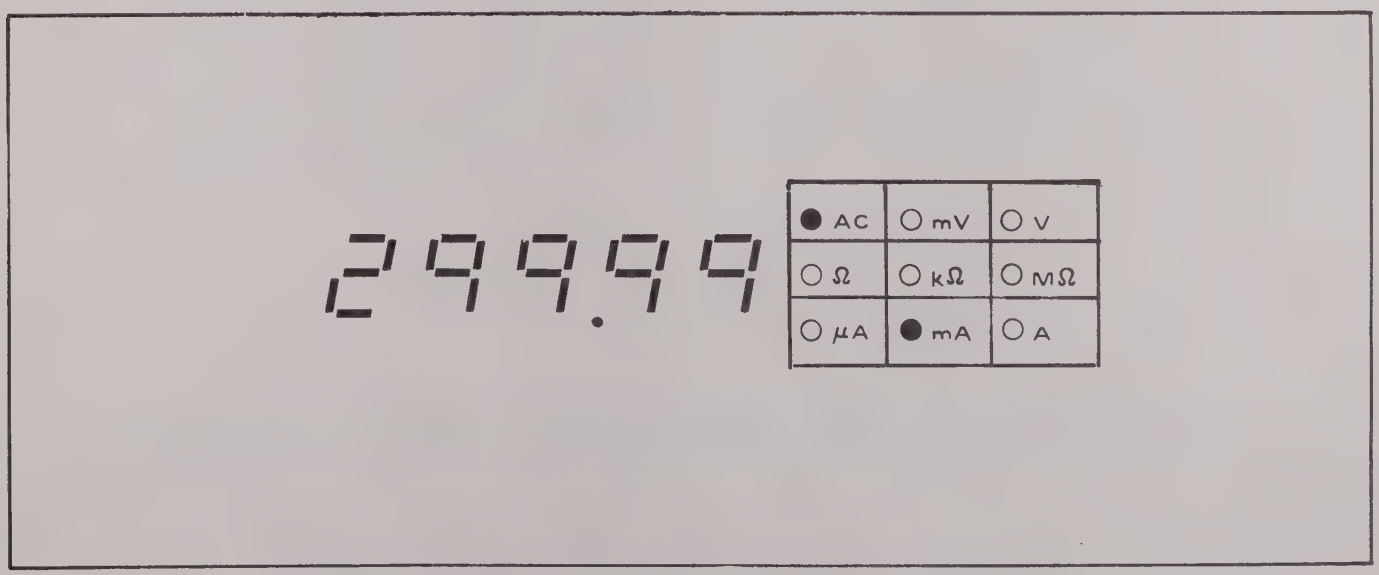


FIGURE 3-2. Typical Model 4004 Current Display (ACmA).

3-7. HOW TO MEASURE RESISTANCE. The Model 4004 DMM measures resistance from 10 milliohms/digit to 300 megohms. The maximum display is 29999. When the display exceeds 29999, a 3 remains lighted, but all other digits are blanked.

a. HI Ohms Measurement. When the HI/LO pushbutton is released (set to HI), the voltage developed across the resistance under test at full range is 3 volts. The Model 4004 DMM measures from 100 mΩ to 300 megohms in HI mode.

1. Set to HI Ohms.
2. Set to 2 WIRE.

NOTE

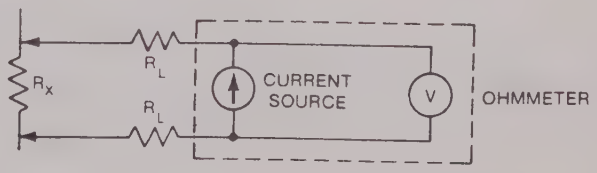
When the Model 4004 DMM is set to 2 WIRE, the lower set of HI and LO input terminals is not connected. When set to 4 WIRE, the higher set of HI and LO input terminals is used as "voltage sensing" terminals. See Section 3-9 for more detailed information.

3. Set to AUTO.
4. Connect the resistance under test between the upper set of HI and LO terminals.
5. Observe the displayed digits, decimal point location, and measurement unit (Ω, KΩ, or MΩ).

b. LO Ohms Measurement. When the HI/LO pushbutton is depressed (set to LO), the voltage developed across the resistance under test at full range is 300 millivolts. The Model 4004 DMM measures from 10 mΩ to 30 megohms in LO mode.

1. Set to LO Ohms.
2. Set to 2 WIRE.
3. Set to AUTO.
4. Connect the resistance under test between the upper set of HI and LO terminals.
5. Observe the displayed digits, decimal point location, and measurement unit (Ω, KΩ, or MΩ).

This illustration is typical of a 2-terminal ohmmeter design.



When measuring resistance less than 1000 ohms it may be necessary to use the 4-wire mode to eliminate the measuring error of the test leads. For example a pair of 10ft leads made from 18 AWG copper wire has 0.14 ohms resistance.

FIGURE 3-3. Typical 2 WIRE Resistance Measurement.

3-8. FURTHER MEASUREMENT CONSIDERATIONS.

a. DC Voltage Measurements.

1. Overloads. When the display exceeds ±1200.0V DC all digits blink to indicate an overload condition.

2. Input Resistance. Input resistance is 1,000 MΩ on the 300mV and 3V ranges; 10 MΩ on the 30V, 300V, and 3000V ranges. The effects of circuit loading should be considered when evaluating total accuracy of measurement. (See Accuracy.)

3. Accuracy. The Model 4004 DMM accuracy is specified in terms of % of reading and a % of range. For a full range reading of 299.99 mV DC the accuracy of measurement would be ± (0.03 mV + 0.01 mV) or ±0.04 mV. Measurements from relatively high source resistances could cause an additional reading error. The amount of error due to loading can be determined by the following relationship:

$$\% \text{ error} = 100 \times Rs \div (Rs + RI)$$

where Rs = source resistance in ohms
RI = input resistance of Model 4004 DMM in ohms

4. Self-Test Feature. The Model 4004 DMM has a bottom cover voltage contact for functional check in DC Volts. To use this feature, connect the input HI terminal to circled B contact. Verify a display of approximately 5 volts dc with V depressed. To check dc current, depress A and verify a display of 1 mA.

b. AC Voltage Measurements

1. Overloads. When the display exceeds 1000.0 V AC (rms) all digits blink to indicate an overload condition.

2. Input Impedance. The input impedance is 2 megohms shunted by less than 50 picofarads. The effects of circuit loading should be considered when evaluating the total accuracy of measurement. (See Accuracy.)

3. AC-to-DC Conversion. The Model 4004 DMM operates as an average-reading voltmeter, calibrated in terms of the root-mean-square (rms) of a sine wave. The calibration is exact for sinusoidal waveforms in the specified frequency range.

4. Frequency Response. The frequency range given in the specifications is the minimum and maximum frequencies which accuracy is valid.

5. Accuracy. 4004 DMM accuracy is specified in terms of % of reading and so many digits. Measurements from relatively high source impedance could cause an additional reading error. The amount of error due to loading can be determined by the following relationship:

$$\% \text{ error} = 100 \times \frac{Zs}{Zs + Zin}$$

where Zs = source impedance
Zin = effective input impedance of DMM

6. Self-Test Feature. The Model 4004 DMM has a bottom cover voltage contact for functional check in AC volts. To use this feature, connect the input HI terminal to circled A contact. Verify a display of approximately 6 volts ac. To check ac current, depress A and verify a display of 1.2 mA.

NOTE

AC Self-test features are operable on line power only.

c. Current Measurements.

1. Overloads. The AC overload fuse is 3A.

2. Shunt Resistance. The Model 4004 develops approximately 300 millivolts across the input terminals at full range.

For example, on the 300 milli-ampere range the shunt resistor is 1.3 ohm, which results in a voltage drop of 0.3 x 1.3 = 390 millivolts at full range.

3. Accuracy. 4004 DMM accuracy is specified in terms of a % of reading and so many digits. An additional reading error should be considered if the source resistance is not greater than 1000 times the shunt resistor. The amount of error can be determined by the following relationship:

$$\% \text{ error} = \frac{100 \times Rin}{Rs + Rin}$$

where Rin = shunt resistance of the DMM
Rs = source resistance.

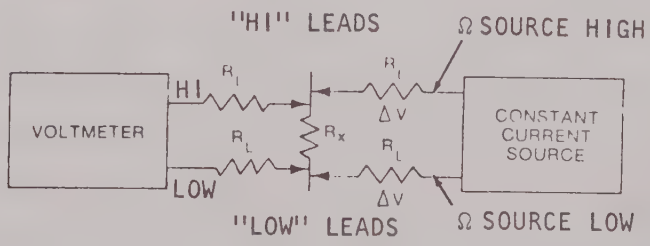
d. Resistance Measurements.

1. Maximum Allowable Voltage Input. The maximum input should not exceed 250V rms sine wave or ±250V dc.

2. Polarity of Ohms. The Model 4004 DMM provides a positive voltage at the HI terminal.

3. Maximum Open-Circuit Voltage. When the HI and LO terminals are open in either HI or LO ohms, the maximum voltage developed between HI and LO is +5 volts.

This illustration is typical of a 4-terminal measuring technique using a separate Voltmeter and Current Source. The DMM combines these features.



When using the 4-WIRE method, connect one pair of "current" leads to Ω SOURCE input. Connect a second pair of "voltage" leads to HI and LO. Then set to 4 WIRE.

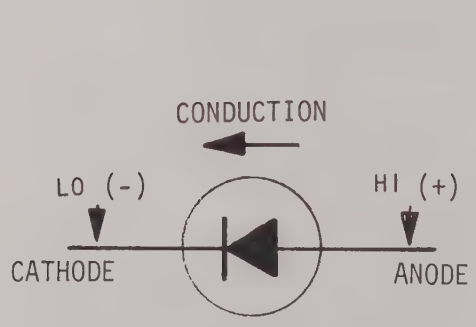
Care should be taken to connect "current" leads and "voltage" leads properly. The LO terminal and Ω Source low must always connect to the same side of the unknown resistance.

FIGURE 3-4. Typical 4 WIRE Resistance Measurement.

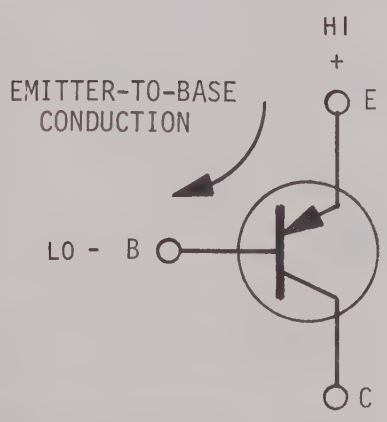
4. Four-terminal Measurements. The 4-WIRE mode connects the lower set of Ω SOURCE terminals to the DMM ohmmeter source. As shown in Figure 3-4 the lower terminals are the current carrying terminals while the upper terminals are the voltage sensing terminals. This arrangement eliminates the error due to voltage drop across the current-carrying leads.

5. Semiconductor Diode and Transistor Testing. The Model 4004 DMM can be used to test diodes and transistors to determine the relative condition of the device. For semiconductor diodes, the voltage applied must be sufficient to cause conduction in the forward direction. The "HI OHMS" mode provides a voltage up to 3 volts at a current upto 1 milliampere. Since the HI terminal is positive with respect to LO terminal, connections should be made as shown in Figure 3-5 to cause forward conduction of diodes. Since the maximum current is available on the 3 KΩ range, depress AUTO/MAN (Set to MAN) and manually range to the 3 KΩ range (down-range).

6. Self-Test Feature. The Model 4004 DMM has a bottom cover voltage contact for functional check in OHMS. To use this feature, place the DMM in OHMS and 2-WIRE mode. Connect input HI terminal to circled C contact. Verify a display of approximately 10 kilohms.



TYPICAL DIODE



TYPICAL PNP TRANSISTOR

FIGURE 3-5. Semiconductor Diode and Transistor Testing.

3-9. HOW TO USE MODEL 4004 DMM OFF-GROUND. The "LO" terminal can be operated off ground at potentials of up to ±1400V. Isolation from the "LO" terminal to power line ground is specified at 1000MΩ, or $10^9\Omega$ (shunted by 300pF). Typically, the isolation resistance from LO to GND is two decades greater than $10^9\Omega$ ($10^{11}\ \Omega$). Because of this excellent isolation, operating the Model 4004 DMM off ground results in very little loading (from LO to GND) of a floating source. At 1000V above ground, the Model 4004 DMM will require, typically, only 10nA from the source. The excellent isolation also accounts for the high common-mode rejection ratio of the Model 4004 DMM . Even with the "HI" terminal driven and a source resistance of 1kΩ, 1000 VDC (from HI to GND) will produce typically only 10μV DC error. This error voltage is determined directly from the ratio of the source resistance to the "isolation" resistance (See Figure 3-7).

$$I \simeq \frac{1000V}{10^{11}\Omega} = 10^{-8}A \qquad V_{across\ 1k} = I \times 1k\Omega = 10^{-8} \times 10^{3} = 10\mu VDC$$

The "isolation" capacitance from LO to GND is important when AC common-mode signals are present. In the Model 4004 DMM this capacitance is specified at 300pF. At a frequency of 60Hz, 300 picofarads has a reactance of approximately 10MΩ. With the HI terminal driven and a source impedance of 1kΩ, a 1000V p-p, 60 Hz, common-mode signal will produce a voltage of only 100mV p-p across the input terminals. This 100mV p-p signal will be further rejected by the input filter and A-D converter so that the total rejection at the digital display is at least 120 dB (HI driven, 1kΩ source impedance). For DC voltage measurements, rejection is much greater than specified when the Model 4004 DMM LO terminal is driven, rather than the HI terminal. Where there is a need for even greater isolation from LO to power line ground, or where there is a need to float at potentials greater than 1400 volts above power line ground the Option 06. Battery Pack should be used.

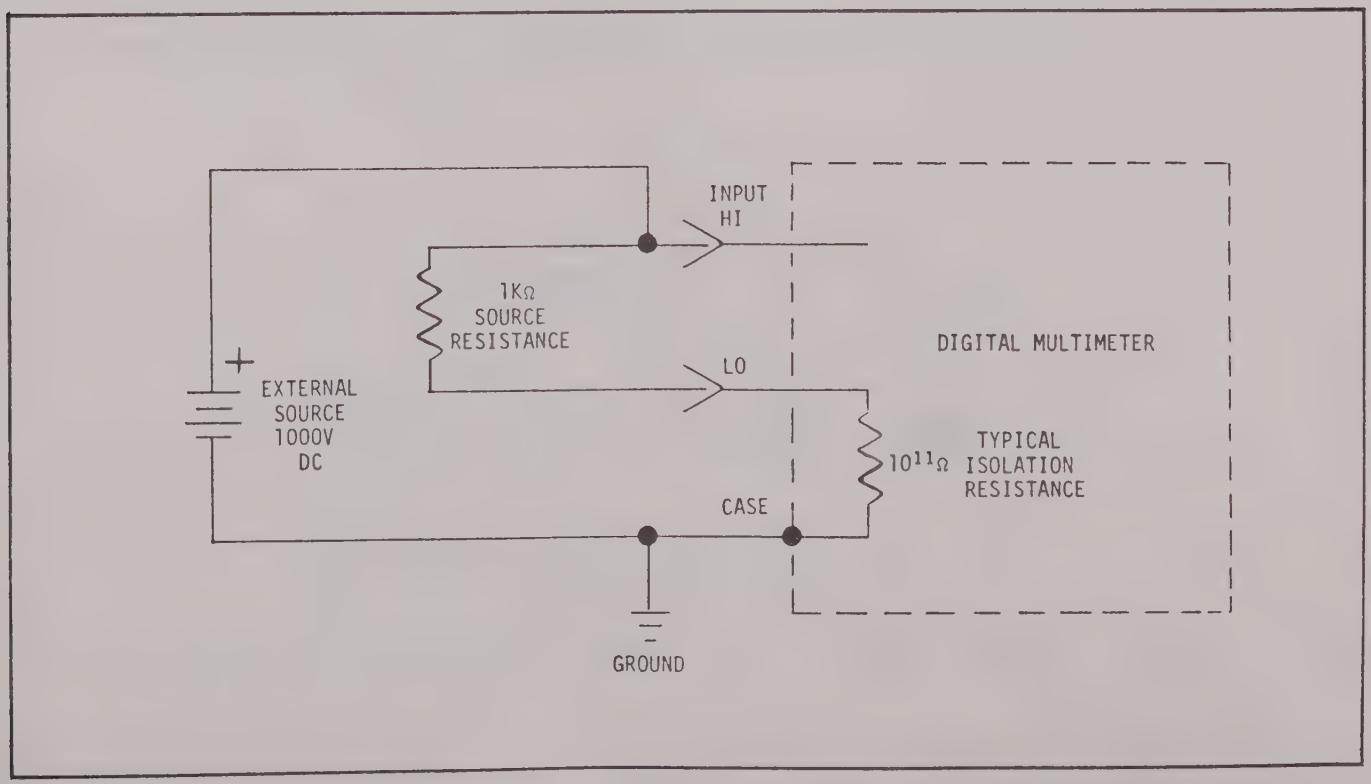


FIGURE 3-6. Use of Multimeter Off Ground.

3-12 HOW TO USE THE OPTION 51 DIGITAL INTERFACE.

a. General. The Option 51 provides binary coded decimal outputs (8421) and range control lines. Outputs are open-collector positive true unless otherwise specified. This accessory is available either "factory installed" or "field-installable". The Option 51 consists of a two-layer circuit with card-edge and mating output connectors.

b. Installation.

1. Disconnect the Model 4004 DMM line cord from line voltage.

2. Turn the instrument over so that the bottom cover faces up.

3. Loosen four slotted screws on the bottom cover. The screws are captive, that is, they cannot be removed completely.

4. Turn over the instrument with the top cover facing up, taking care to hold the top and bottom covers together.

5. Carefully remove the top cover to gain access to the printed circuit board. There is one connection between the top cover and the main circuit board which must be temporarily removed in order to free the top cover.

6. Remove the Option 06 Rechargeable Battery Pack (if installed). Carefully disconnect connectors from the mother board.

NOTE

The Options 06 and 51 cannot be installed on the Model 4004 DMM chassis at the same time.

7. Check to see that the four insulating spacers are in position on the circuit board as shown in Figure 3-8.

8. Place the Option 51 on the spacers as shown in Figure 3-8.

9. Lift up the Option 51 slightly to gain access to the Model 4004 DMM mother board, and plug in connectors J1003, J1002, and J1001 (in order given).

10. Connect ground return wire from the Option 51 to the extra lug on transformer T101.

11. Replace the connections to the top cover.

12. Reinstall the top cover.

13. Turn the instrument over and tighten the four screws.

c. Connector Terminations. The Option 51 uses two card-edge connectors P1006 (40-pin) and P1101 (26-pin). Ribbon cable style of mating connectors may be used with these cardedge connectors as shown in Table 3-5.

TABLE 3-5.
Summary of Mating Connectors

	Manufacturer	Crimped Ribbon-Cable Style
P1101	3M	3462-0000
P1006	3M	3464-0000

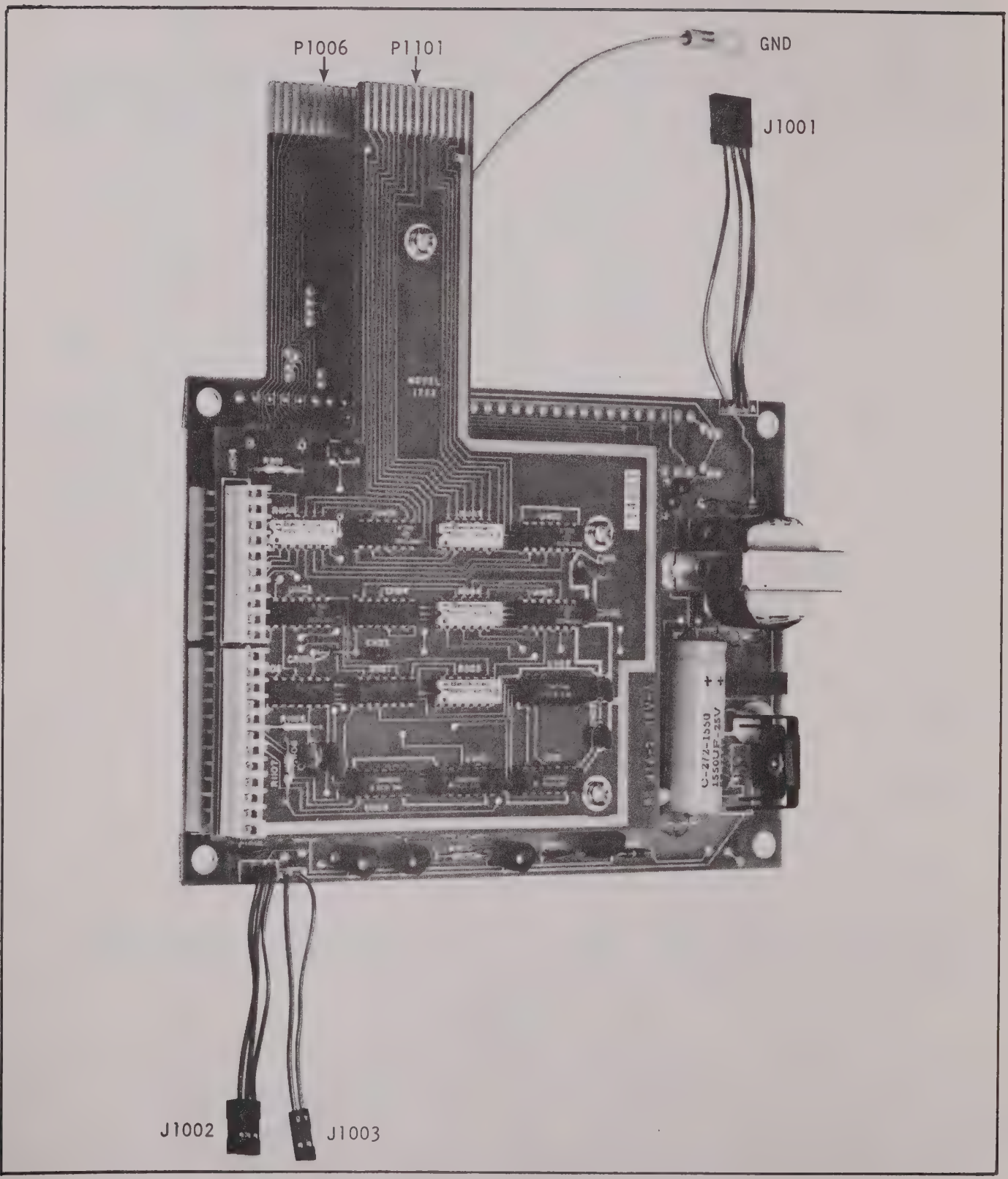


FIGURE 3-7. Option 51 Digital Output Interface .

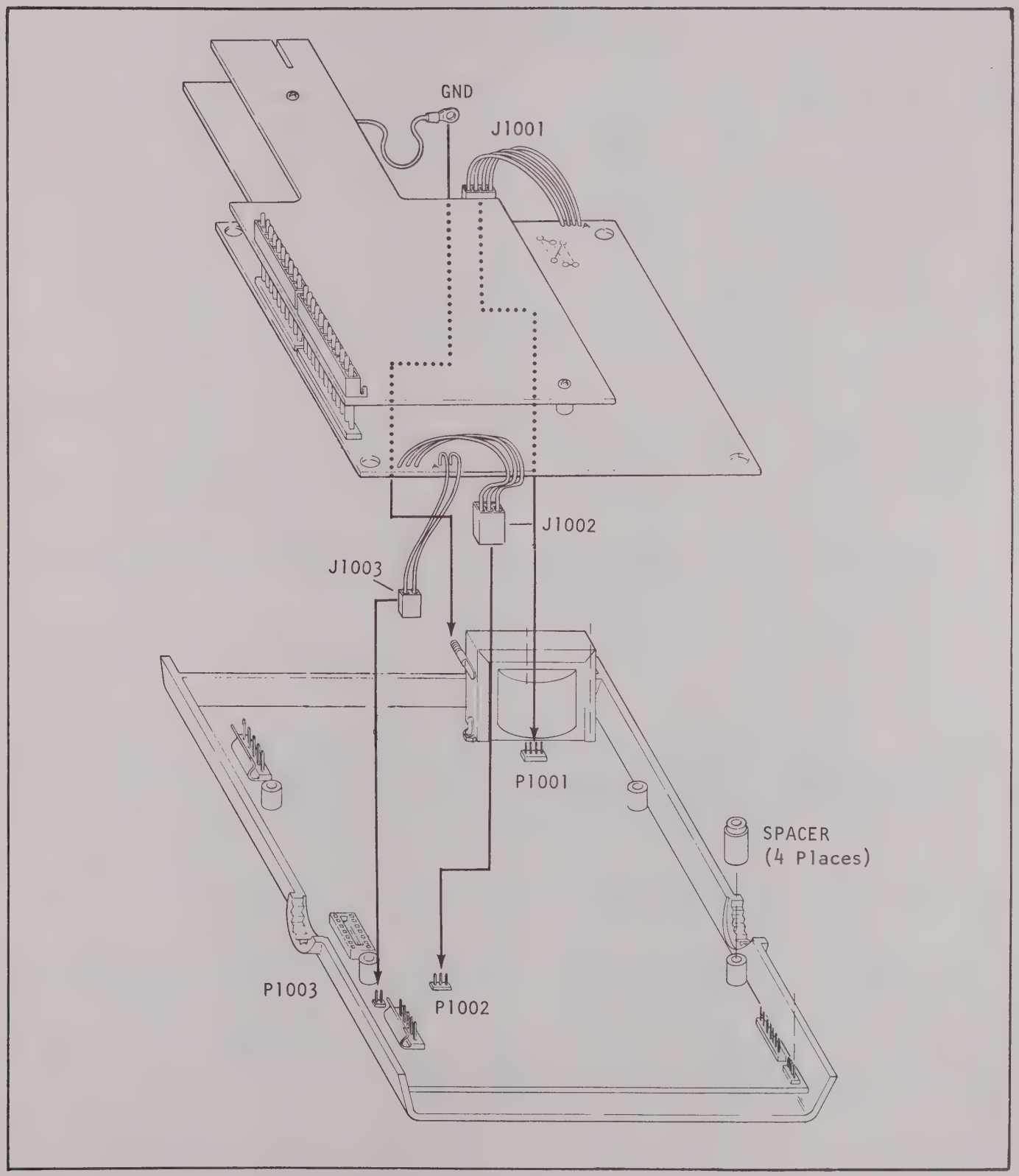


FIGURE 3-8. Installation of Option 51.

TABLE 3-6.
Summary of Digital Output at P1006

Pin No.	Signal	Pin No.	Signal
1	CASE GND	21	10^4-2
2	COMMON	22	10^3-2
3	COMMON	23	10^4-1
4	COMMON	24	10^3-1
5	COMMON	25	10^2-8
6	PRINTER HOLD	26	10^1-8
7	AUTOMODE	27	10^2-4
8	VEXT	28	10^1-4
9	R8	29	10^2-1
10	VOLTS	30	10^1-2
11	R4	31	10^2-1
12	AMPS	32	10^1-1
13	R2	33	10^0-8
14	AC	34	$\overline{\text{FLAG}}$
15	R1	35	10^0-4
16	OHMS	36	FLAG
17	10^4-8	37	10^0-2
18	10^3-8	38	OVERFLOW
19	10^4-4	39	10^0-1
20	10^3-4	40	POLARITY

TABLE 3-7.
Summary of Remote Commands at P1101

Pin No.	Command	Pin No.	Command
1	CASE GND*	14	RANGE $\overline{\text{STROBE}}$
2	COMMON	15	R4
3	COMMON	16	POLARITY $\overline{\text{STROBE}}$
4	AUTORANGED $\overline{\text{STROBE}}$	17	R8
5	$\overline{\text{TRIGGER MODE}}$	18	10^4 $\overline{\text{STROBE}}$
6	AUTOMODE $\overline{\text{STROBE}}$	19	TRIGGER
7	HOLD	20	10^3 $\overline{\text{STROBE}}$
8	OVERFLOW $\overline{\text{STROBE}}$	21	$\overline{\text{FLAG RESET}}$
9	$\overline{\text{LOAD RANGE}}$	22	10^2 $\overline{\text{STROBE}}$
10	FLAG/$\overline{\text{FLAG}}$ $\overline{\text{STROBE}}$	23	$\overline{\text{TRIGGER MODE DISABLE}}$
11	R1	24	10^1 $\overline{\text{STROBE}}$
12	FUNCTION $\overline{\text{STROBE}}$	25	$\overline{\text{AUTORANGED}}$
13	R2	26	10^0 $\overline{\text{STROBE}}$

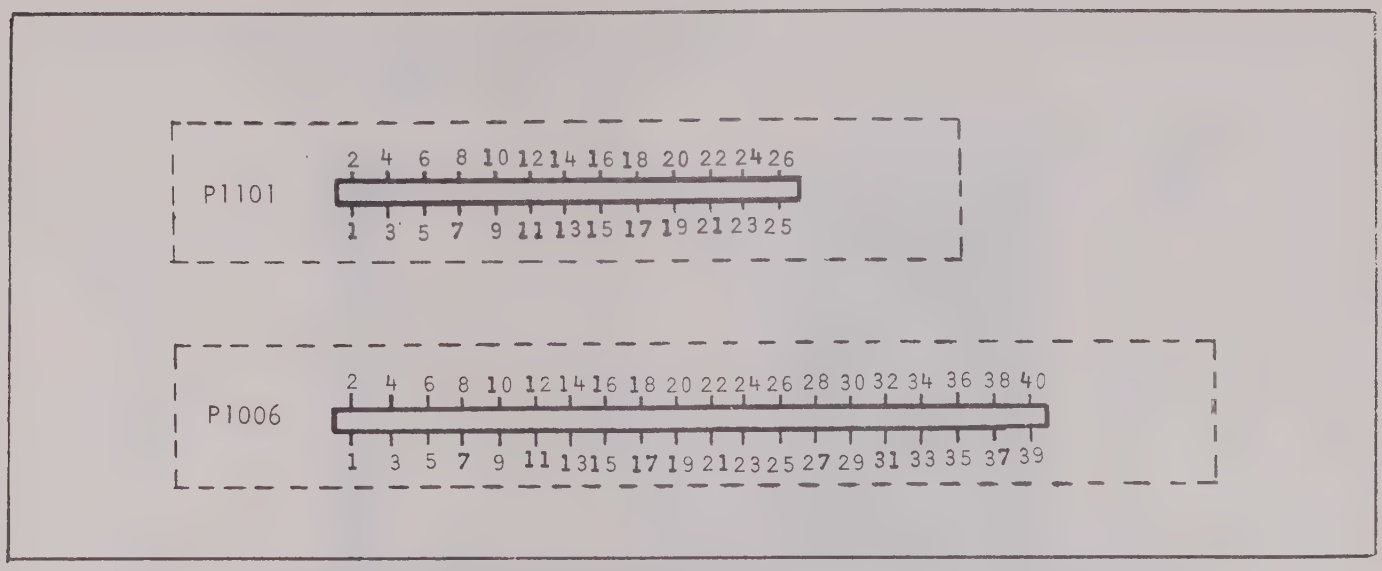


FIGURE 3-9. Connector Pin Identification for P1006 and P1101.

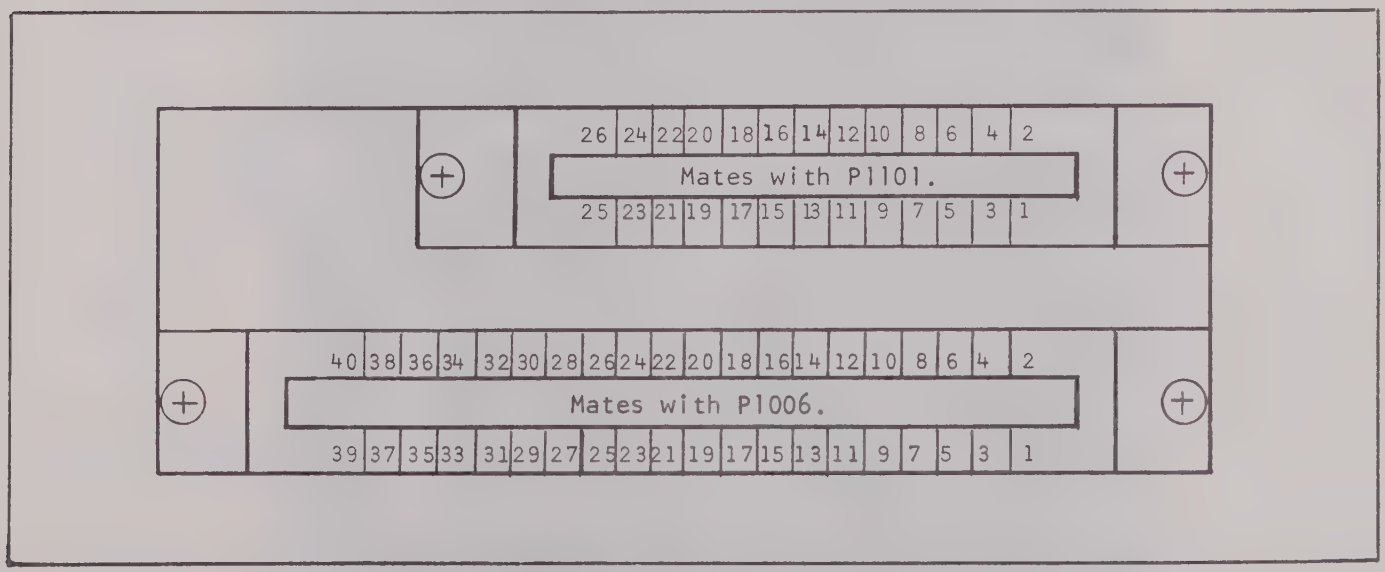


FIGURE 3-10. Card-Edge Connectors

d. How to Select Vext Using Internal Jumper. The Option 51 may be wired for use with internal or external voltage references and internal pull-up resistors. (See Figure 3-11).

1. Jumper A. When this jumper is installed, the pull-up resistors are connected to the external reference Vext (pin 8, P1006).

2. Jumper B. When this jumper is installed, the pull-up resistors are connected to the internal reference (+5V).

3. Jumper C. When this jumper is installed, Vext is connected to internal +5V reference. The pull-up resistors are not connected in this instance. The +5 volt reference is rated at 40 mA maximum.

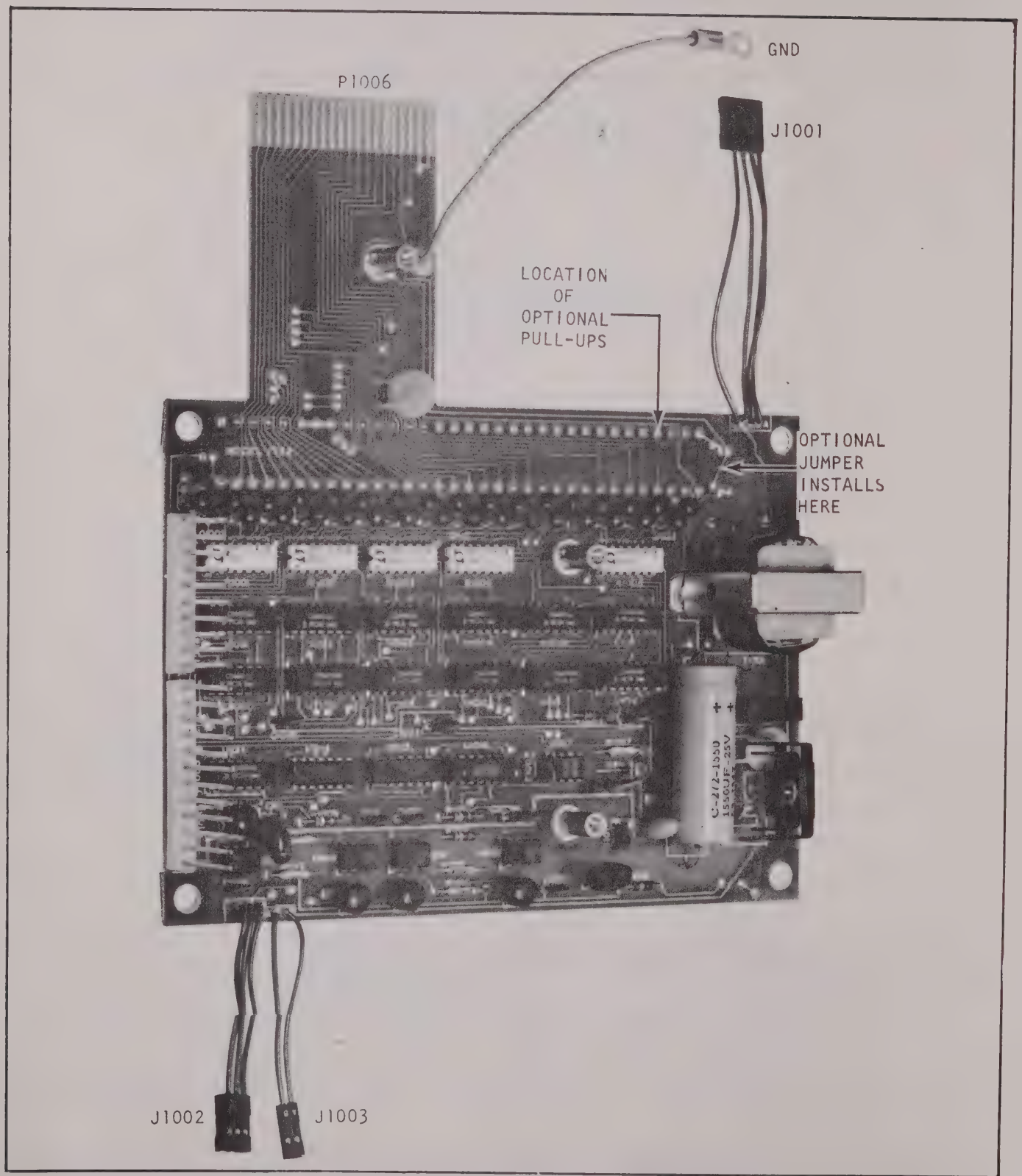


FIGURE 3-11. Location of Jumpers and Pull-Ups on Option 51

TABLE 3-8.
Digital Output Lines Grouped By Function

Name	P1006 Pin No.	P1101 Pin No.
10^0 STROBE	--	26
10^0-1	39	
10^0-2	37	
10^0-4	35	
10^0-8	33	
10^1 STROBE	--	24
10^1-1	32	
10^1-2	30	
10^1-4	28	
10^1-8	26	
10^2 STROBE	--	22
10^2-1	31	
10^2-2	29	
10^2-4	27	
10^2-8	25	
10^3 STROBE	--	20
10^3-1	24	
10^3-2	22	
10^3-4	20	
10^3-8	18	
10^4 STROBE	--	18
10^4-1	23	
10^4-2	21	
10^4-4	19	
10^4-8	17	
POLARITY STROBE	--	16
RANGE STROBE	--	14
-R1	15	
-R2	13	
-R4	11	
-R8	9	

Name	P1006 Pin No.	P1101 Pin No.
FUNCTION STROBE		12
-VOLTS	10	
-AMPS	12	
-AC	14	
-OHMS	16	
OVERFLOW STROBE		8
-OVERFLOW	38	
AUTOMODE STROBE		6
-AUTOMODE	7	
AUTORANGED STROBE		4
-AUTORANGED		25
PRINTER HOLD	6	
TRIGGER MODE		5
HOLD		7
LOAD RANGE		9
R1		11
R2		13
R4		15
R8		17
TRIGGER		19
FLAG RESET		21
TRIGGER MODE DISABLE		23
COMMON	2,3,4,5	2,3
CASE	1	1
FLAG/FLAG STROBE	--	10
FLAG	36	
FLAG	34	
VEXT	8	

TABLE 3-9.
General Characteristics of Option 51 Digital Interface.

DIGITAL OUTPUTS:
Logic: BCD (8421) Open-collector positive true unless otherwise specified.
Data: 4 full digits, 1 partial digit (0, 1, 2, 3) and exponential range code.

Function: 4-bit code (Ω, AC VOLTS, AMPS)
Polarity: HIGH ≡ +.
Overflow: LOW ≡ > 29999.
Autorange: LOW ≡ range change.
Automode: HIGH ≡ autorange mode.

FLAG (FLAG): HIGH (logic "0" ≡ no output change occuring.
Logic Levels: HIGH ≡ open collector to output LO. LOW ≡ closure to output LO. Output device (2N5134) greater than 20V breakdown, <0.5V at 5mA sink (3TTL loads). Internal pull-up resistors may be installed on these open collector outputs. 4.7K minimum value is recommended when using internal 5 volt power supply.

OUTPUT TIMING: Data is updated typically every 320 msec (non-trigger mode). Update time is typically 1.2 msec. Data will appear at an output only if its respective strobe is active. The FLAG will go low (Logic "0") typically 2 msec before update and go high typically 100 µsec after update. Data can be expected to be unchanging so long as the flag is high. If FLAG RESET is activated, the FLAG will reset (go to Logic "0") until the end of the next data update.

REMOTE CONTROLS:
Strobe: Strobe lines permit word serializing in 4-bit increments or multiples thereof. HIGH inhibits controlled output lines from conduction, LOW enables conduction.
Range In: 4-bit exponential code.
Load Range: Low enables remote ranging as set by Range code.
Hold: LOW inhibits display update, output update and autorange (A/D continues conversions).
Printer Hold: Same as hold but grouped with outputs for convenience in interfacing printer.
Trigger Mode: LOW enables TRIGGER control.
Trigger Mode Disable: LOW disables TRIGGER.
Trigger: LOW to HIGH transition initiates a new A/D conversion.
Flag Reset: LOW sets FLAG (FLAG) to LOW (HIGH).
Control Logic Levels & Source Requirements: HIGH ≡ either an open circuit or a voltage between +2.4V and 5V referred to output LO. LOW ≡ closure to output LO within 0.8V while sinking +1.6 milliamperes (1TTL load). When TRIGGER MODE, HOLD and LOAD RANGE code bits are all HIGH (inactive) the 4004 DMM is under front panel control. These REMOTE CONTROL inputs have priority and will override any front panel setting once activated.

ISOLATION: All digital outputs and remote controls are isolated from 4004 DMM analog input by 10^9 Ω and 500pF, 1200 VDC, 1000V rms AC maximum. All digital outputs and remote controls are isolated from chassis ground by 10^6 Ω and 0.01µF; 250V rms maximum.

e. Detailed Explanation of Option 51 .

TRIGGER MODE AND TRIGGER: (See Schematic 28248E)

When TRIGGER MODE is active (Low), output data and display will not be updated. TRIGGER MODE enables TRIGGER. Conversion starts within 1.6 milliseconds after TRIGGER. Integration starts 120 milliseconds after start of conversion.

HOLD:

If either HOLD or PRINTER HOLD is low the output data and the display will not be updated and the FLAG will stay at HIGH (unless reset by FLAG RESET).

LOAD RANGE:

When LOAD RANGE is low the 4004 DMM will go to the range as set by the RANGE IN code (Table 3-10) at the beginning of the next conversion. As long as LOAD RANGE is held low, the instrument will remain on its programmed range overriding front panel UPRANGE, DOWNRANGE and AUTORANGE. RANGE IN codes programmed outside the limits of Table 3-10 will result in the nearest valid range to that programmed. LOAD RANGE will always cause a DMM range change. However, the display and output data will be held (not updated) during TRIGGER MODE or HOLD.

REMOTE CONTROLS:

Referring to timing schematic 28249D, it is possible to just miss a REMOTE CONTROL update prior to data output. This can be misleading, especially in the case of HOLD. A HOLD just missed (unknown to the user), just before data begins to change, could result in erroneous data. To check if this occurred, it is suggested that the FLAG be examined no sooner than 10 µsec after activation of the HOLD bit. If flag is low wait until it goes to HIGH before expecting the HOLD bit to have been accepted. Other REMOTE CONTROL bits such as TRIGGER MODE and TRIGGER, LOAD RANGE and the RANGE IN code can be kept active for longer than an output data update time, i.e. >3.2 msec to insure proper REMOTE CONTROL acceptance.

TRIGGER MODE DISABLE: (See Schematic 28249D)

When in TRIGGER MODE and triggering into an autoranging condition, normal operation will give an output for each range encountered during the autorange. However, if this is undesirable the AUTORANGED output bit can be tied to TRIGGER MODE DISABLE and FLAG RESET. This will prevent the FLAG from being set and ignore further triggering until the final range is reached.

V_{ext}:	Internal jumpers (user installed) select internal or external voltage reference for user-installed pullup resistors for all open-collector outputs, or applies internal +5V to V_{ext} (maximum external current load on internal +5V is 40mA). Minimum pull-up resistor recommended is 4.7K.
LINE GROUND:	One pin on each output connector.
GROUNDS:	4 pins for digital outputs, 2 pins for remote control.
CONNECTORS:	One 40-pin card edge and one 26-pin card edge.

ENVIRONMENT:

Installed in a 4004 DMM : Operating 0°C to 55°C, humidity 80% @ 35°C.
Storage: -25° to +65°C

f. Modifications to Model 4004 DMM Specifications. When operating DMM with an Option 51 in TRIGGER MODE, only the accuracy specifications for the top two ohms ranges change as follows:

HI Ω 300MΩ Range:	From 1% of reading to 1.5% of reading.
HI Ω 30MΩ Range:	From 0.15% of reading to 0.2% of reading.
LO Ω 30MΩ Range:	From 0.5% of reading to 1% of reading.
LO Ω 3MΩ Range:	From 0.1% of reading to 0.15% of reading.

Also when operating in TRIGGER MODE, repeatability of readings may be up to:

0.5% on 300MΩ Hi Ω and 30MΩ Lo Ω ranges, and
0.05% on 30MΩ Hi Ω and 3MΩ Lo Ω ranges.

Accuracy of all other ohms ranges and all other functions is not affected by the Option 51 when operating in TRIGGER MODE.

TABLE 3-10

Option 51 RANGE & FUNCTION CODING FOR MODEL 4004

FUNCTION	OUTPUT FUNCTION CODE (1)	RANGE	OUTPUT RANGE CODE (1)	(EXP)	INPUT RANGE CODE (1) (3)	
	V A AC Ω		R_8 R_4 R_2 R_1		R_8 R_4 R_2 R_1	
DC VOLTS	1 0 0 0				1 1 1 1	AUTORANGE
		300 mV	0 1 0 1	5	1 0 1 0	
		3.0V	0 1 1 0	6	1 0 0 1	
		30 V	0 1 1 1	7	1 0 0 0	
		300 V	1 0 0 0	8	0 1 1 1	
		1200 V	1 0 0 1	9	0 1 1 0	
AC VOLTS	1 0 1 0				1 1 1 1	AUTORANGE
		300 mV	0 1 0 1	5	1 0 1 0	
		3 V	0 1 1 0	6	1 0 0 1	
		30 V	0 1 1 1	7	1 0 0 0	
		300 V	1 0 0 0	8	0 1 1 1	
		1000 V	1 0 0 1	9	0 1 1 0	
DC AMPS	0 1 0 0				1 1 1 1	AUTORANGE
		300 µA	0 1 0 1	5	1 0 1 0	
		3 mA	0 1 1 0	6	1 0 0 1	
		30 mA	0 1 1 1	7	1 0 0 0	
		300 mA	1 0 0 0	8	0 1 1 1	
		3 A	1 0 0 1	9	0 1 1 0	
AC AMPS	0 1 1 0				1 1 1 1	AUTORANGE
		300 µA	0 1 0 1	5	1 0 1 0	
		3 mA	0 1 1 0	6	1 0 0 1	
		30 mA	0 1 1 1	7	1 0 0 0	
		300 mA	1 0 0 0	8	0 1 1 1	
		3 A	1 0 0 1	9	0 1 1 0	
LOW Ω	0 0 0 1				1 1 1 1	AUTORANGE
		300 Ω	0 0 1 0	2	1 1 0 1	
		3 kΩ	0 0 1 1	3	1 1 0 0	
		30 kΩ	0 1 0 0	4	1 0 1 1	
		300 kΩ	0 1 0 1	5	1 0 1 0	
		3 MΩ	0 1 1 0	6	1 0 0 1	
		30 MΩ	0 1 1 1	7	1 0 0 0	
HI Ω	0 0 1 0				1 1 1 1	AUTORANGE
		3 kΩ	0 0 1 1	3	1 1 0 0	
		30 kΩ	0 1 0 0	4	1 0 1 1	
		300 kΩ	0 1 0 1	5	1 0 1 0	
		3 MΩ	0 1 1 0	6	1 0 0 1	
		30 MΩ	0 1 1 1	7	1 0 0 0	
		300 MΩ	1 0 0 0	8	0 1 1 1	

(1) Coding in this table is defined to be HIGH (POSITIVE) TRUE. "1" = HIGH and "0" = LOW. Refer to output and remote control logic levels for definitions of HIGH & LOW.

(2) Function code for Model 4004 current is volts.

(3) Note that except for AUTORANGE CODE, INPUT & RANGE CODE is the compliment of the OUTPUT RANGE CODE, i.e. the INPUT RANGE CODE is the LOW TRUE BCD code of (EXP).

3-12. COMMENTS RELATIVE TO THE MODEL 4004 DMM SPECIFICATIONS. Above 1 ampere there is a decrease in accuracy. This decrease in accuracy is due to self heating and the temperature coefficient of the resistors that are used in these currents. This degradation in accuracy will not exceed those values that are listed in the specification sheet. However, prolonged operation at the high currents for instance, 3 amperes on the 4004 DMM may give temporary zero shifts because of the thermals which are generated due to the self heating of the devices.

3-13. Option 06 OPERATING TIPS. Although the manufacturers of the nickel cadmium batteries used in the 06 claim that their cells can be charged at a C/10 rate indefinitely, once a cell is fully charged, the energy fed to the cell is converted to heat, which increases the temperature of the cell. If cells are overcharged at C/10 rate for extended periods of time (weeks), this may cause cell degradation. Racal-Dana recommends that the Option 06 not be overcharged for extended periods to maximize useful battery life. Trickle charging should have no effect on useful battery life. Nickel Cadmium batteries also exhibit a memory effect. If the 06 is only used to operate the instrument for relatively short periods of time (1 or 2 hours) the 06 may not be able to provide the full operating time of 6 hours.

Do not operate the Multimeter in BAT mode after the LO BAT indicator is lighted. The discharge characteristic of Nickel Cadmium batteries is such that it maintains a fairly constant 1.2V through most of its discharge cycle. At the end of the discharge curve the cell voltage drops fairly rapidly to zero volts. After a given cell in the battery pack drops to zero it is reverse charged by the rest of the cells in series with it. Although the cells used in the 06 are guaranteed by the manufacturer to withstand reverse charge for 10% of their discharge time, it is not a good practice to continually reverse charge cells, as more rapid cell degradation may occur.

The cells used in the 06 should give a minimum of 250 discharge/charge cycles and typically 500 discharge/charge cycles. Thus, based on daily useage (5 day week, one per day) the battery pack should give a minimum of one year operation and typically two years. Longer life should be expected for less frequent useage.

TABLE 3-11

Summary of Fuses and Miscellaneous Replaceable Parts

ITEM	WHERE USED	RACAL-DANA PART NO.
Fuse, 3 AB/3 AG, 1/4 A, Slo-Blo	117V Line Volts	FU-17
Fuse, 3 AB/3 AG, 1/8 A, Slo-Blo	234V Line Volts	FU-20
Fuse, 3 AB/3 AG, 1 A, Slo-Blo	Option 06	FU-10
Fuse, 3 AB/3 AG, 3 A Quick	Model 4004 Amperes	FU-2
Top Cover (less metalcal)	-	28969C
Bottom Cover (less metalcal)	-	28968B
Handle (less insert)	-	25729D
. . Insert	-	26090A
Rubber Foot	-	FE-10

SECTION 4. ACCESSORIES

4-1. GENERAL. This section describes the various accessories and options available for use with the Model 4004 DMM Digital Multimeter.

4-2. POWER OPTIONS. The Model 4004 DMM can be powered by line voltage (105-125V standard) or rechargeable Battery Pack (Option 06). Other line voltage ranges are available as described in Section 2. The Option 06 is available factory-installed or field-installable.

4-3. ISOLATED DIGITAL OUTPUT. The Option 51 Digital Output Interface is available factory-installed or field-installable. Complete specifications are given in Section 3 (paragraph 3-12.)

IMPORTANT

The Option 51, 55T and 06 cannot be installed and used at the same time since these options occupy the same location on the Model 4004 DMM chassis.

4-4. RACK MOUNTING. The Model 4004 DMM can be rack mounted in a full rack (19 inch width) in either a single or dual mounting configuration.

OPTION 60 SINGLE RACK MOUNTING KIT

Description:

The Option 60 is a single rack mounting kit with overall dimensions 5-1/4 in. (133 mm) high and 19 in. (483 mm) wide. The hardware included in this kit includes a 19 inch wide panel and other miscellaneous hardware.

Application:

The Option 60 adapts one Model 4004 instrument for Standard 5-1/4 in. (133 mm) x 19 in. (483 mm) rack mounting with 11 in. (280 mm) depth behind the front panel. For dual rack mounting the Option 65 Dual Rack Mounting Kit must be used.

Parts List:

Item No.	Description	Qty Req'd	Racal-Dana Part No.	Illustration
1	Front Panel	1	26595D	
2	Support Plate (Shelf)	1	26599C	
3	Bracket, Left Side	1	26600B	
4	Bracket, Right Side	1	26601B	
5	Slotted Screw, #6-32 x 2-1/4 in.	2	--	
6	Flat Washer, #6	2	--	
7	Phillips Screw, #8-32 x 1/2 in.	10	--	

Assembly Instructions:

1. Using two Phillips Screws (Item 7) attach Support Plate (Item 2) to Front Panel (Item 1).

2. Using four Phillips Screws (Item 7), attach left and right side Brackets (Items 3 and 4) to Front Panel (Item 1).

3. Using four Phillips Screws (Item 7), secure left and right side Brackets to Support Plate (Item 2).

4. Assembly of rack hardware is complete except for mounting of Instrument.

5. Rotate "handle" of Instrument so that handle is toward rear of Instrument. (Handle can be removed completely if desired by separating top and bottom covers.)

6. Remove two Slotted Screws (1-1/4 in. long) used to hold top and bottom covers together near front feet.

7. Position Instrument so that holes in bottom of Instrument align with two front holes on Support Plate.

8. Using two Slotted Screws (Item 5) and two Flat Washers (Item 6), secure Instrument to Support Plate.

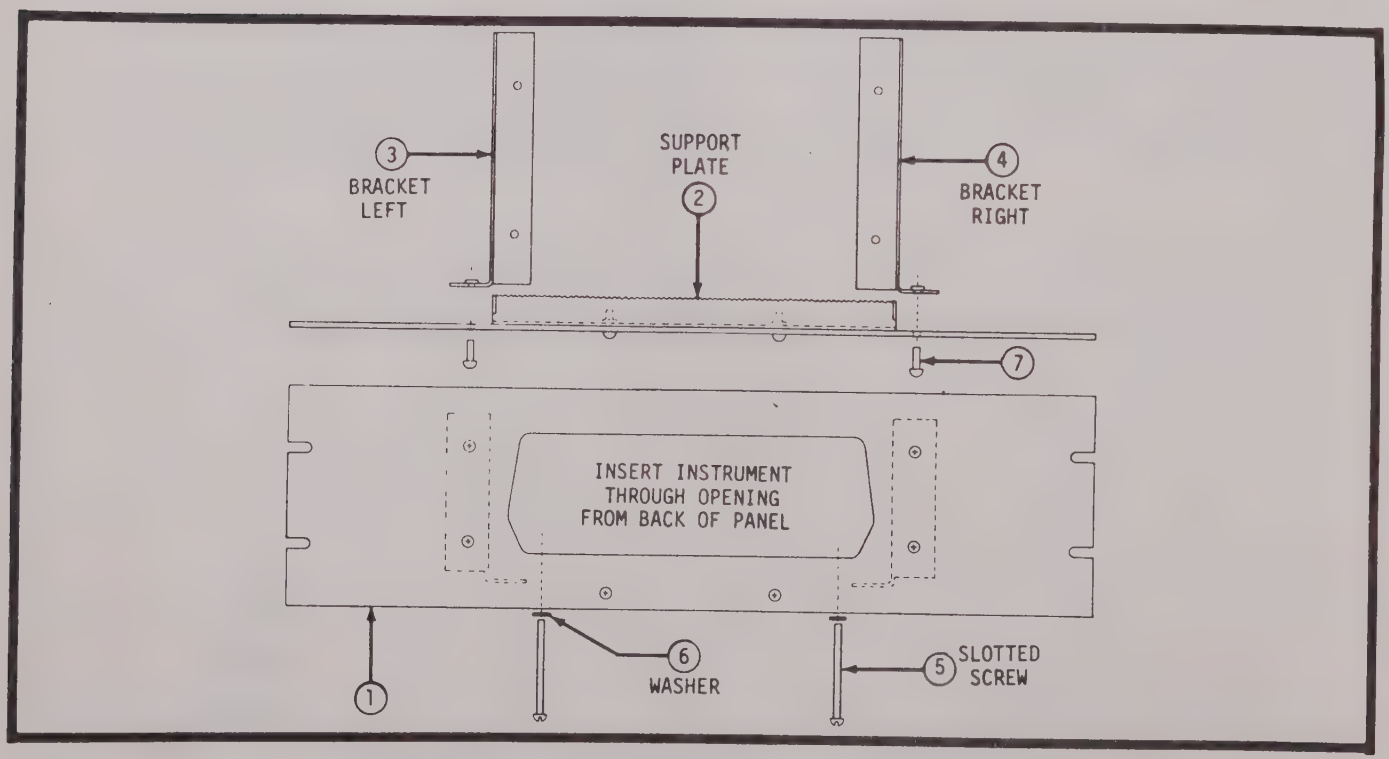


FIGURE 4-1. Option 60 Single Rack Mounting Kit.

OPTION 65 DUAL RACK MOUNTING KIT

Description:

The Option 65 is a single/dual mounting kit with overall dimensions 5-1/4 in. (133 mm) high and 19 in. (483 mm) wide. The hardware included in this kit includes a 19 inch wide panel, and other miscellaneous hardware.

Application:

The Option 65 adapts two Model 4004 DMM instruments for Standard 5-1/4 in. (133 mm) x 19 in. (483 mm) rack mounting with 11 in. (280 mm) depth behind the front panel.

Parts List:

Item No.	Description	Qty Req'd	Racal-Dana Part No.	Illustration
1	Front Panel	1	28092D	
2	Support Plate (Shelf)	1	28094C	
3	Bracket, Left Side	1	28096B	
4	Bracket, Right Side	1	28097B	
5	Slotted Screw, #6-32 x 2-1/4 in.	4	--	
6	Flat Washer, #6	4	--	
7	Phillips Screw, #8-32 x 1/2 in.	4	--	
	Blank Cover Plate	1	28098B	
8	Hole Plug	2	HP-20	
9	Kep Nut, #8	5	--	

Assembly Instructions: (See Figure 4-2, page 4-4.)

1. Using four Phillips screws (Item 7) attach left and right hand Side Plates (Items 3 and 4) to the Support Plate (Item 2).
2. Using three Kep Nuts (Item 9) attach the Support Plate (Item 2) to Front Panel (Item 1).
3. Fasten the Side Plates to the Front Panel using two additional Kep Nuts (Item 9).
4. Assembly of rack hardware is complete except for mounting of the Instrument(s).
5. The plastic tilt bail/handle on each instrument must be removed before mounting. The top and bottom covers of the instrument must be disassembled in order to remove the handle. Loosen four screws on the bottom cover of the instrument, lift off the top cover, and remove handle. Replace the top cover and tighten the four screws on the bottom cover.
6. Remove two Slotted Screws (1-1/4 in. long) used to hold top and bottom covers together near the front feet on each instrument. These screws are captive and a needle-nose pliers should be used to pull the screw out after it is loosened with a screwdriver.
7. Position the Instrument so that holes in the bottom of the Instrument align with the two front holes in the Support Plate.
8. Using two Slotted screws (Item 5) and two Flat Washers (Item 6) secure the Instrument to the Support Plate.

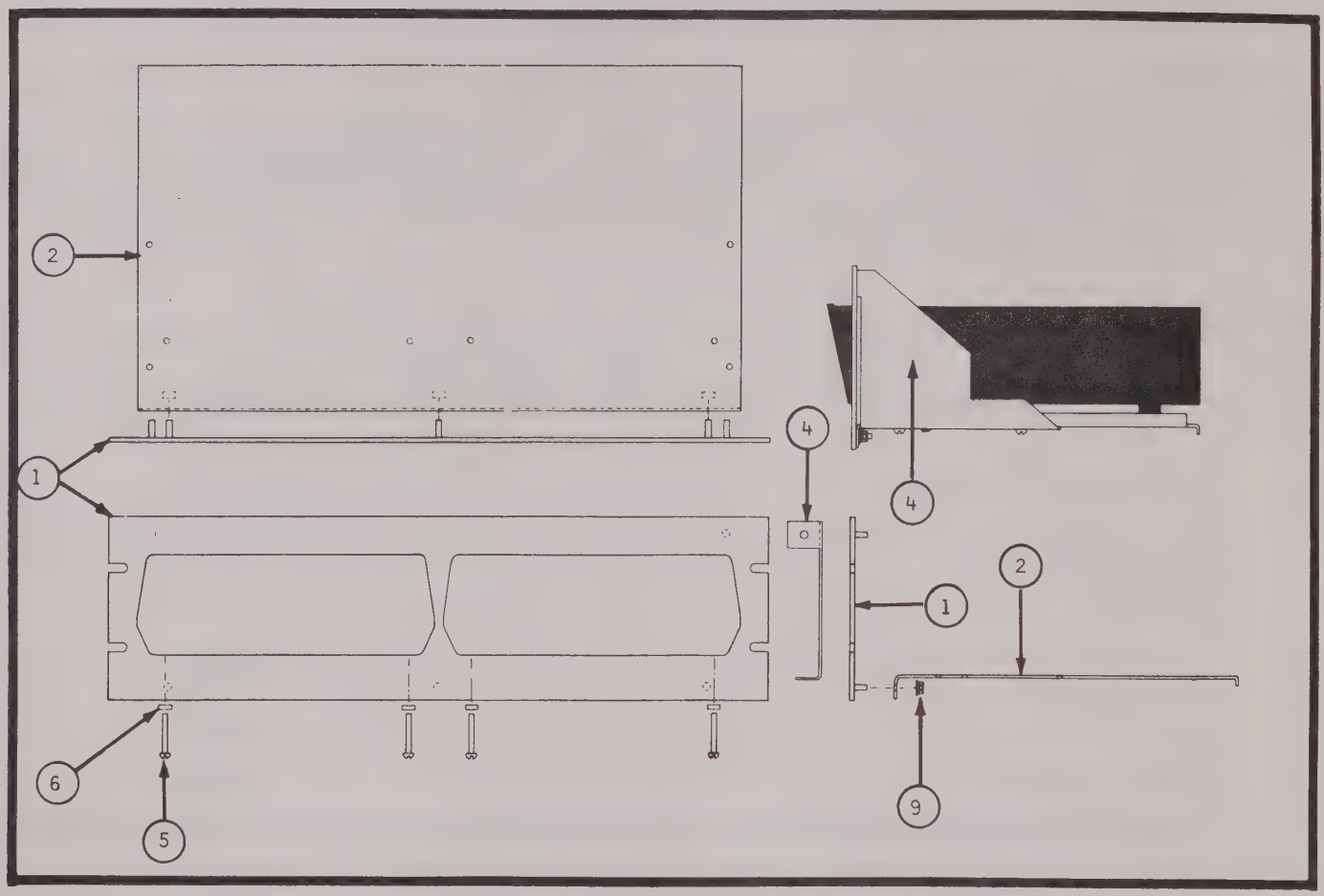


FIGURE 4-2. Option 65 Dual Rack Mounting Kit.

4-5. MISCELLANEOUS.

OPTION 70 MAINTENANCE KIT

Description: The Option 70 contains a specially punched calibration cover for accessability to adjustment controls on the Model 4004 DMM chassis. The kit also contains test leads and a copy of this manual.

SECTION 5. THEORY OF OPERATION.

5-1. GENERAL. This section contains circuit descriptions for the Model 4004 DMM, Option 06 battery pack and Option 51 Digital Interface option. (It should be noted that the Theory of Operation for the Option 55T, IEEE Standard 488 Bus Interface option is provided under separate cover, see Option 55T Instruction Manual.) The descriptions contained in this section are broken down into the following major categories.

a. Overall Operation.

b. Input Signal Conditioning.

c. A/D Converter and Digital Circuits.

d. Display Board.

e. Power Supply.

f. Battery Pack (Option 06).

g. Digital Interface (Option 51).

5-2. OVERALL OPERATION. The overall signal flow of the Model 4004 is shown in Figure 5-1.

a. Input Signal Conditioning. An input to the DMM (a resistance, a dc voltage or current, or an ac voltage or current) is applied to the appropriate signal conditioning circuit. The output from the signal conditioning circuit is a filtered dc voltage in the range of either 0 to ±3 volts or 0 to ±300 millivolts, which is directly proportional to the input signal within the measurement range.

b. A/D Converter and Digital Circuits. The A/D converter changes the voltage out of the signal conditioning circuitry into digital pulses by the charge balance technique, and these pulses are accumulated by the digital circuitry during the measurement conversion period. At the end of this period, the digital circuitry uses the total count to determine the correct polarity and value of the digitized input signal, which is then displayed with the appropriate polarity, range, decimal point location and function on the LED display. The A/D converter auto calibrates and autozeros itself, as well as the signal conditioning circuitry, to obtain a high measurement accuracy.

c. Digital Interface Options. The display information of the Model 4004 DMM can also be made available as an output by using either the Option 51 Digital Interface or the Option 55T-IEEE Standard 488 Bus Interface. Both of these optically isolated options can also be used to program range, trigger a conversion, or hold the reading of the DMM.

d. Power Supply. The power supply furnishes regulated dc voltages for all of the DMM circuitry, and receives its power from either the ac line or the option 06 Rechargeable Battery Pack.

5-3. INPUT SIGNAL CONDITIONING. Most of the input signal conditioning circuitry is contained on the main printed circuit board (mother board) PC-466 and shown on schematic 29145E (Sheet 1). These circuits consist of input switching, an ohms converter, a dc attenuator, an ac/dc converter, a clamp and an active filter. The current to voltage (I/V) converter circuitry is located on the current board PC-406.

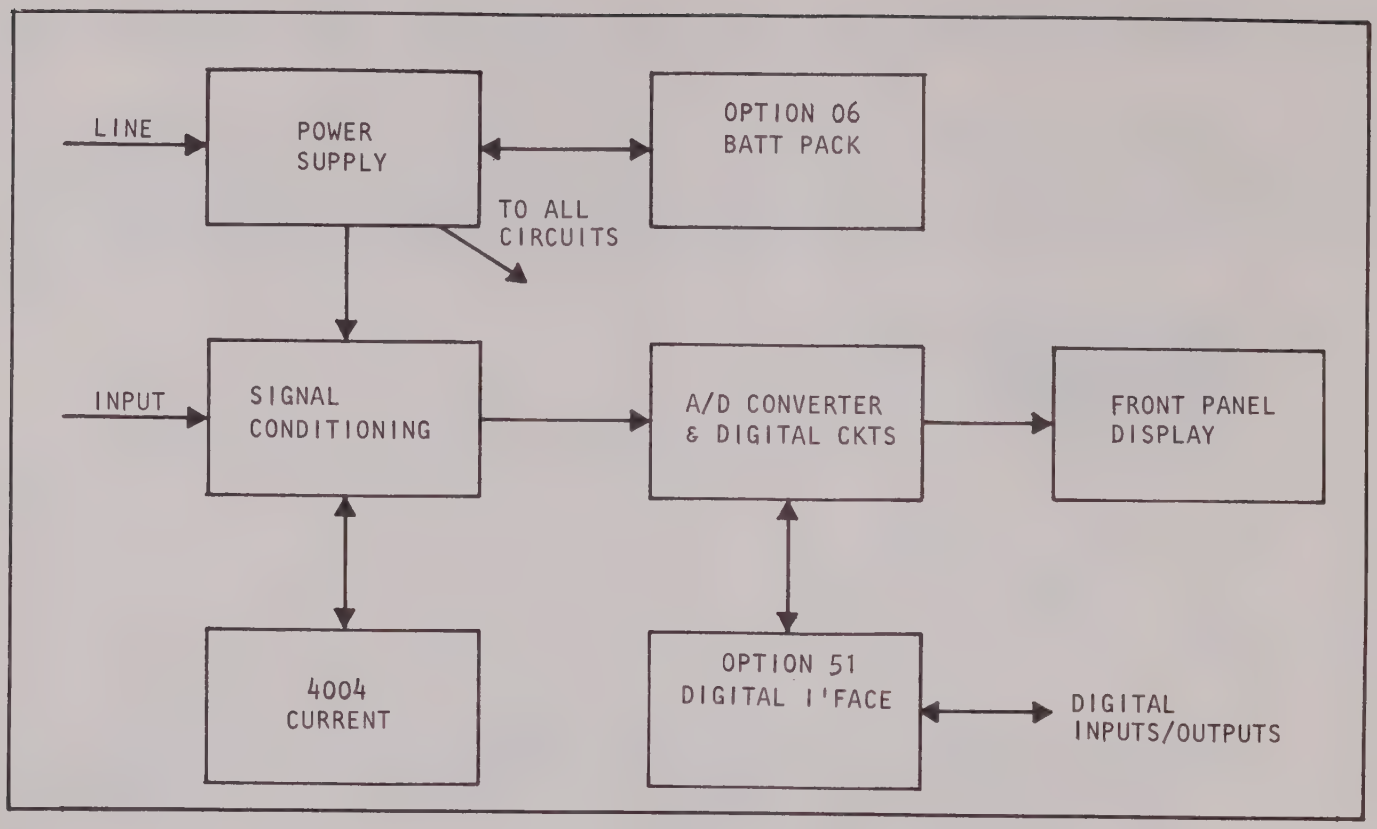


FIGURE 5-1. Overall Block Diagram of Model 4004 DMM .

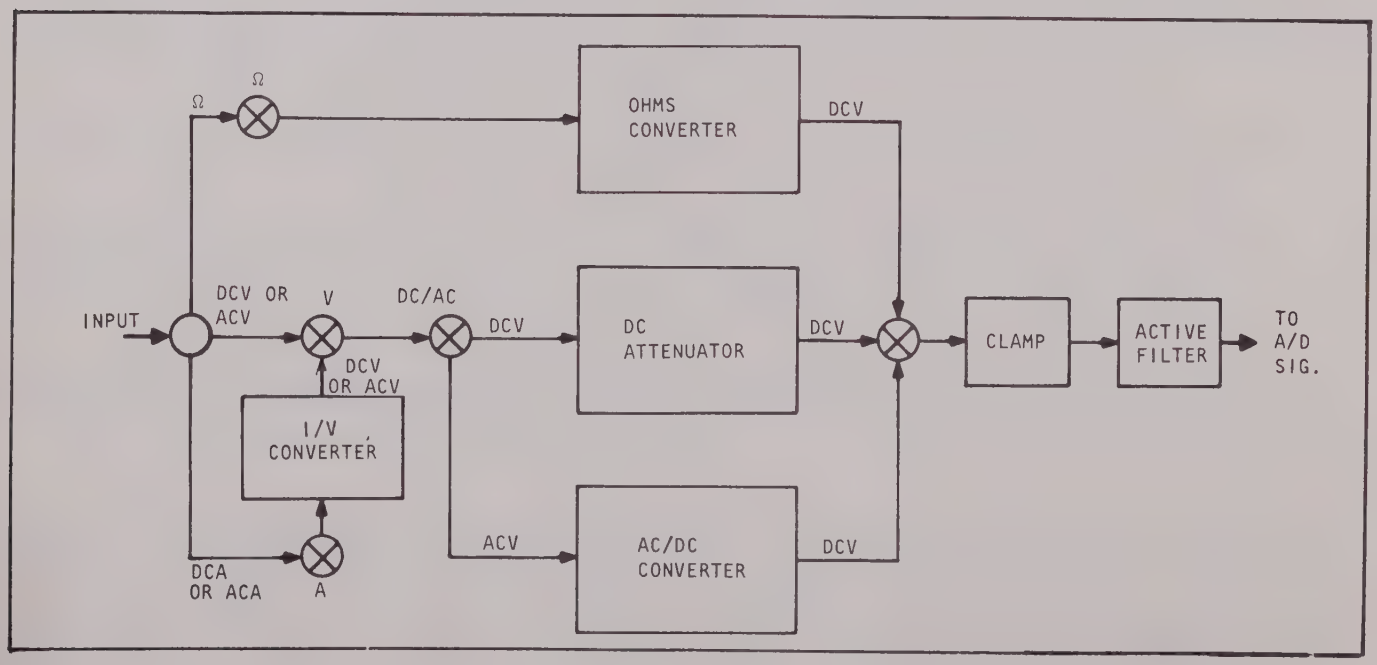


FIGURE 5-2. Simplified Block Diagram of Signal Conditioning Circuits.

a. Overall Operation. Signal routing in the signal conditioning circuitry is essentially as shown in the simplified block diagram (Figure 5-2). Front panel switching selects the applicable path for the input signal. For example, an ac current input would be routed through switch "A" to the I/V converter. The ac voltage output from the I/V converter would be routed through the "V" switch and the "DC/AC" switch to the AC/DC converter, and the dc voltage output of this circuit would then be routed to the AD converter through the clamp and active filter. The required switching and signal conditioning for an ohms or voltage input can also be readily determined from the diagram, and is left to the user. The front panel switching and signal conditioning circuits will be described in greater detail in the following paragraphs.

b. Switching. Front panel pushbutton switches control power, function and ranging for the Model 4004 DMM. A summary of the switching is given in Table 5-1. Additional information on function selection and range selection switching is given in Paragraphs 5-3i and 3j, respectively.

TABLE 5-1.
Summary of Pushbutton Switching.

SWITCH	STYLE	SETTING	REMARKS
LINE	Push-Push	In (On)	DMM is powered by ac line power. Battery pack (if installed) has a trickle charge.
LINE	Push-Push	Out (Off)	DMM is disconnected from line power. Battery pack (if installed) is charged at maximum rate if line cord is connected to power.
BAT	Push-Push	In (On)	DMM is powered by internal Battery Pack.
BAT	Push-Push	Out (Off)	DMM is disconnected from Battery Pack.
			NOTE Interlock prevents both LINE and BAT pushbuttons IN at the same time. Both pushbuttons must be set to OUT before either can be set to IN. Push-Push means that a single depression will place the pushbutton to IN, a second depression will release the pushbutton to OUT.
AUTO/MAN	Push-Push	In	DMM is set to MAN (Manual Mode). To change range, depress either DN RANGE or UP RANGE. See also REMOTE PROGRAMMING OPTION.
AUTO/MAN	Push-Push	Out	DMM is set to AUTO (Automatic Ranging Mode.) DMM range is set automatically.
DN Range	Momentary	In	Momentary depression causes the DMM to down range one decade to greater sensitivity. Operable only when AUTO/MAN is IN.
UP Range	Momentary	In	Momentary depression causes the DMM to up range one decade to lesser sensitivity. Operable only when AUTO/MAN is IN.

TABLE 5-1. (CON'T)
Summary of Pushbutton Switching.

SWITCH	STYLE	SETTING	REMARKS
V	*Interlock	In	DMM is set to V mode. Overrides A and Ω functions due to interlocked pushbuttons.
A	*Interlock	In	DMM is set to A mode. Overrides V and Ω functions due to interlocked pushbuttons.
Ω	*Interlock	In	DMM is set to Ω mode. Overrides V and A functions due to interlocked pushbuttons, also overrides DC/AC switch. *NOTE If V, A, and Ω pushbuttons are OUT simultaneously, no function will be selected, the input terminals will be open-circuited, and the DMM will display V. The displayed reading is meaningless.
DC/AC	Push-Push	In	DMM is set to measure AC (either V or A). Not functional when set to Ω.
DC/AC	Push-Push	Out	DMM is set to measure DC (either V or A).
HI/LO**	Push-Push	In	DMM is set to low ohms function.
HI/LO**	Push-Push	Out	DMM is set to high ohms function.
2 WIRE/4 WIRE**	Push-Push	In	DMM is set for 4-WIRE ohms measurements. Upper pair of terminals are used for voltage sensing. Lower pair of terminals are used for ohms source. Lower pair of terminals are useable only in 4-WIRE Ω mode and are open circuited for all other conditions.
2 WIRE/4 WIRE**	Push-Push	Out	DMM is set for conventional 2-WIRE ohms measurements. Upper pair of terminals must be used. Lower pair of terminals are open-circuited. **NOTE Only functional when set to Ω.

1) The dc attenuator is shown on the simplified schematic (Figure 5-3). On the 300mV and 3V ranges, K202 is de-energized as shown and no attenuation occurs. Above ±3 volts, K202 will energize. This means that the output on the 30V and 300V ranges will be 1/100 of the input as derived from the following equation.

$$\frac{100K}{150K + 9.75M + 100K} = \frac{1}{100}$$

2) For 1200 voltrange, switch Q206 will also be on, which makes the output 1/1000 of the input. Thus, for all dc ranges, a full scale dc voltage input will result in either a ±3 volt or ±300 millivolt output from the attenuator, and the A/D converter gain (buffer) will be X1 or X10 accordingly. Table 5-2 lists the respective gains for dc voltage (and ac voltage) ranges.

TABLE 5-2.
Gain Chart For AC/DC Voltage.

RANGE	ATTENUATION	A/D GAIN	RANGE CONTROL LINES RLD	H
300 mV	÷1	X10	+8 V	-12 V
3 V	÷1	X1	+8 V	-12 V
30 V	÷100	X10	0 V	-12 V
300 V	÷100	X1	0 V	-12 V
1000 V	÷1000	X1	0 V	+8 V

d. AC/DC Converter.

1) The basic transfer function of the AC/DC converter is a shown on the simplified schematic (Figure 5-4). The resistor values were selected so the $1Vacrms_{in} = -1Vdc_{OUT}$. Above 3 volts, feedback resistance (R_f) is reduced to keep the output always less than -3Vdc. The dc output is a half-wave rectified sine wave, and the converter is average responding, calibrated to the rms value of a sine wave.

2) C_1 blocks dc inputs, and the dc offset voltage of the amplifier is autozeroed out. C_4, R and C provide some output filtering, along with the active filter (to be described later.)

3) In actual circuit operation (as shown on Schematic 29145E, Sheet 1) feedback resistance of U201 is controlled by K201 and K101. With both relays de-energized as shown, the overall gain of the ac/dc converter is unity (i.e. 1 VACrms input = -1Vdc out). With only K201 energized, gain is ÷100, and with both relays energized gain is ÷1000. The relays are controlled by the relay drivers shown in the lower left corner of the schematic. The relay drivers are, in turn, controlled by signals from the RLD and H lines from LSI circuit U901. See Table 5-2 for gain chart of the ac voltage ranges.

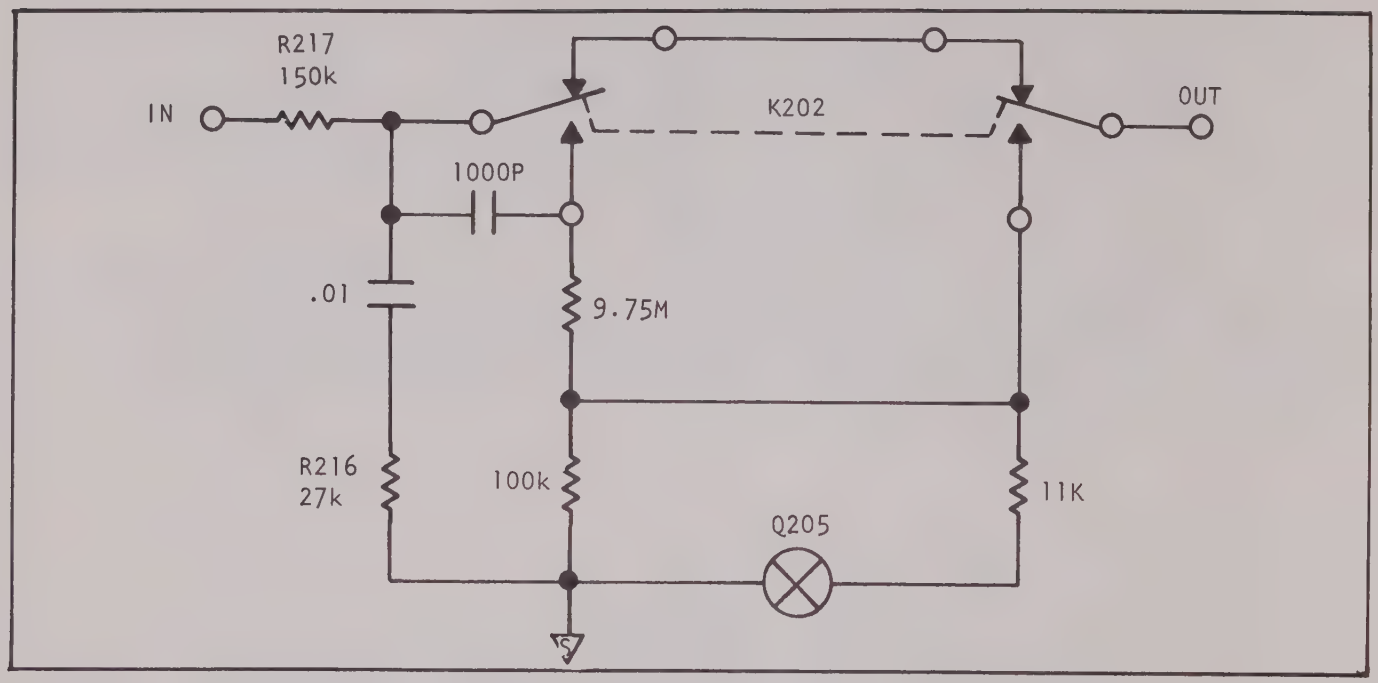


FIGURE 5-3. Simplified Schematic of DC Attenuator.

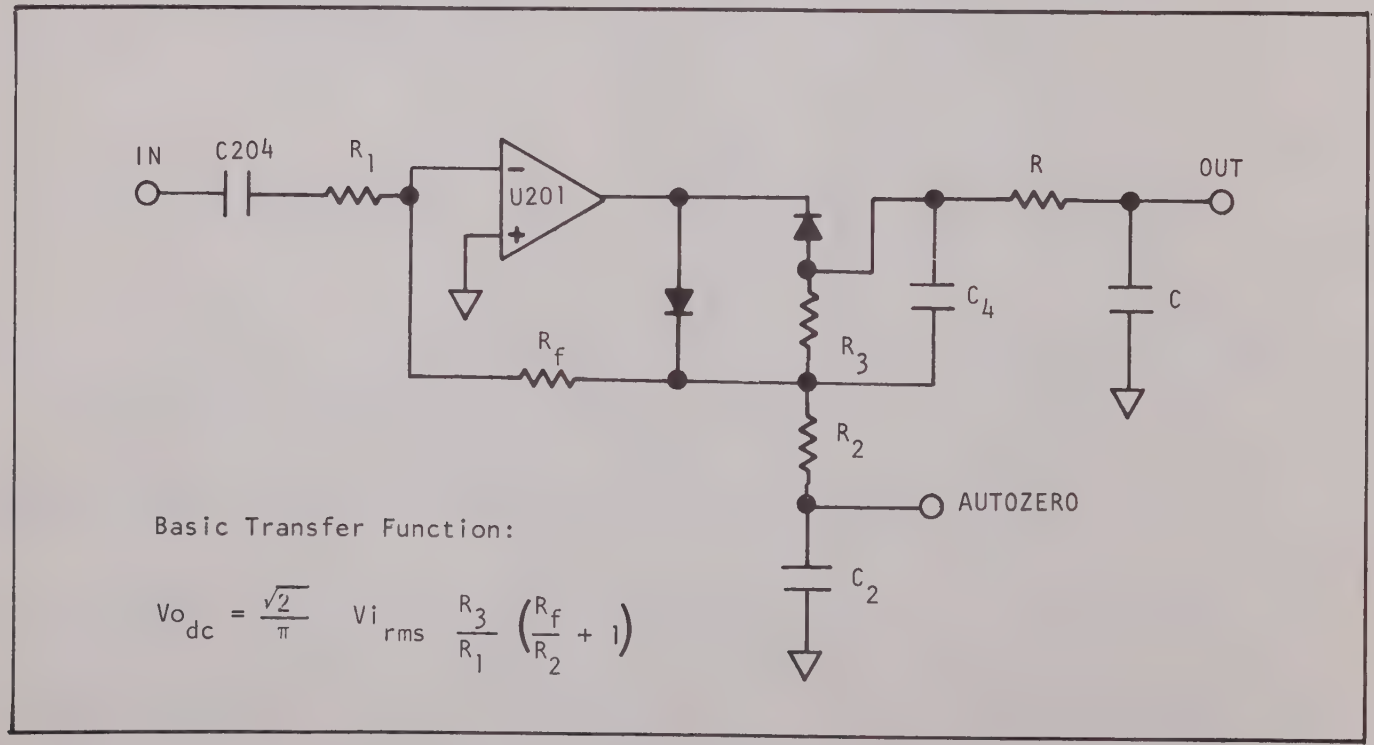


FIGURE 5-4. Simplified Schematic of AC/DC Converter.

e. Current-to-Voltage (I/V) Converter.

1) Model 4004 I/V Converter. The converter is shown on the simplified schematic (Figure 5-5). An input current is converted to a voltage directly proportional to the input current by measuring the voltage drop across a resistance placed in series with the current. This is accomplished by closing the appropriate range relay (K501 through K505) to give an output voltage between 0 and 300 millivolts. For example: Consider that K503 is closed. The current will now flow through 9Ω + 0.9Ω + 0.1Ω = 10Ω, and 30mA = 300mV. Since a dc current is converted to a dc voltage and an ac current is converted to an ac voltage, the output of the I/V converter is routed through either the DC attenuator circuit or the AC/DC converter before being applied to the A/D converter. Signal routing is controlled by the DC/AC pushbutton and the gains employed are the same as those given in Table 5-2 for the 300mV range. Input protection for the I/V converter consists of a 3 ampere medium acting fuse (F501) and a diode bridge (CR501). The fuse is rear panel accessible. CR501 limits the voltage to 2 diode drops in either positive or negative polarity. Unity gain buffer amplifier U501 guards the center connections of the diodes so that less than one digit error is introduced on the 300µA range, which has 10 nanoampere sensitivity. Refer to Schematic 27478D for the remainder of this discussion. Range control lines (A, B and C from LSI chip U901) autorange the Model 4004 current function. The lines are decoded by the BCD to decimal decoder U502 (See Table 5-3). The output from U502 turns on the applicable relay driver transistor to energize its range relay. Diodes are used to block the range lines when -12V is applied and input dividers are used to drop +8V to +5 volts for application to U502. Spike suppression diodes are used across the relay coils to prevent damage to the relay drivers. Potentiometers R506, R509 and R512 provide adjustments for calibrating the I/V converter. With the exception of the fuse, all of the I/V converter circuitry is physically located on current PC-406 and shown on Component Layout diagram 27884C in Section 7.

TABLE 5-3.
Model 4004 Current Ranging.

RANGE ACA & DCA	RANGE RESISTANCE	RELAY OPERATED	RANGE LINE LEVELS A	B	C
300 A	1K	K501	+8V	-12V	+8V
3mA	100Ω	K502	+8V	-12V	-12V
3 A	10Ω	K503	-12V	+8V	+8V
300mA	1Ω	K504	-12V	+8V	-12V
3 A	0.1Ω	K505	-12V	-12V	+8V

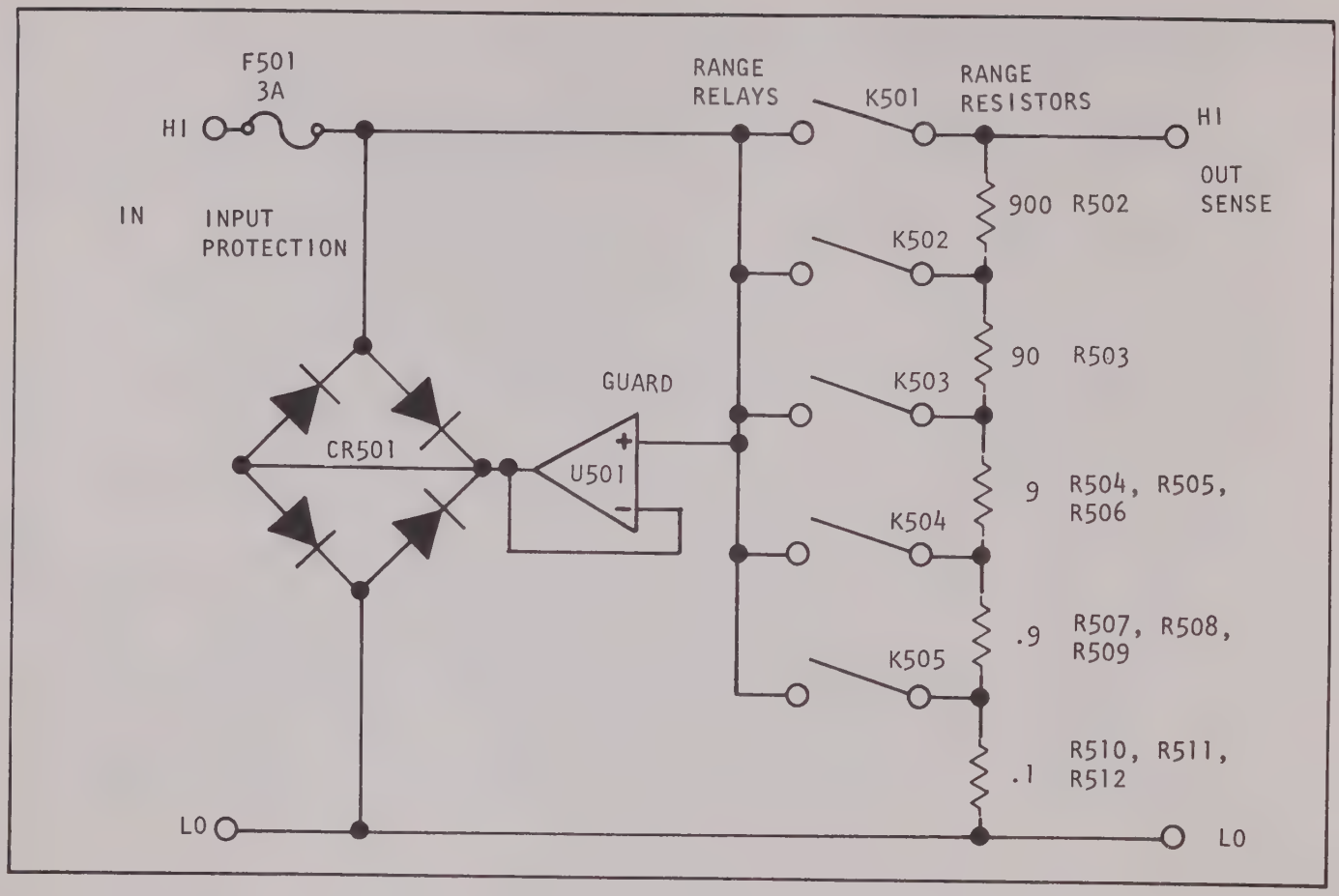


FIGURE 5-5. Simplified Schematic of 4004 I/V Converter.

f. Ohms Converter.

1) The ohms converter circuit basically consists of a current generator and summing amplifier. Simplified operation for the two wire ohms configuration is shown in Figure 5-6.

2) The current is generated by applying either 3.34 or .334 volts (Ohms Cal. Voltage) from buffer amplifier U101 to the Range resistors. The unknown resistances (Rx) is placed in the feedback loop of the summing amplifier (U202) to force the current through the unknown resistor. Thus, the output signal to the A/D converter for an on range measurement can be determined by the equation $-V_{odc} = I \cdot R_X$. The current flowing through R_X is determined by the equation $I = \frac{V_{Ohms\ CAL.}}{R_{Range}}$

Six decade currents are generated by the six combinations of the three range resistors and two levels of ohms cal voltage. Example: $\frac{.334V}{334K} = 1\mu A$. This current is used on 300KΩ LOΩ range and 3M HIΩ range (3V max.)

3) See Table 5-4 for ohms ranges. High ohms puts the A/D converter on the 3 Volt range, allowing 6 resistance ranges which can turn on semiconductor junctions for on scale readings. Low ohms puts the A/D converter on the 300mV range, allowing 6 resistance ranges which do not turn on semiconductor junctions for on scale readings.

4) There are time and temperature drifts associated with amplifiers U101 and U202. These effects are compensated for by the A/D converter. The reference used to calibrate the A/D converter in Ω function is the output of U101. Therefore, any drift in U101 is compensated for every conversion cycle. The negative input of U202 is what "auto-zero" 1 is calibrated to every conversion cycle. Therefore, ohms current stability is a function only of the stability of the Range resistor. The lead drop in the high terminal of the ohms source amplifier is compensated for by connecting it to "auto-zero" 2 when in the ohms mode. "Auto-zero" 2 is the zero for the input signal. In 2-wire ohms the leads connect at the front panel binding post. Therefore, a 4-terminal ohms system exists up to the front panel terminals. See A/D converter discussion for a more thorough explanation of error correction.

5) The ohms converter circuit has been further simplified and redrawn to show the 4-Wire ohms configuration in Figure 5-7.

a. As previously described, the circuit measures a resistor by putting a constant current through Rx and measuring the voltage drop across Rx, which is accomplished by putting Rx in the feedback of a summing amplifier (Ω AMP) whose input is a reference (Ω Vref) voltage through an input resistor (RΩ).

b. AZ-1, ACAL, AZ-2, & A/D Signal are the 4 A/D inputs. This A/D operation compensates for time & temperature variation of Ω VRef and Ω Amp, as well as compensating for lead resistance. The A/D looks at each of these inputs in the time sequence as follows:

1) AZ-1 looks at Ω AMP input for 40 ms and stores this zero level.

2) ACAL looks at Ω VREF for 40 ms and calibrates itself to the difference between AZ-1 and ACAL. Thus, it is calibrated to the voltage across RΩ. Since RΩ is a fixed stable resistor the value of I is now known. Since I flows through Rx the calibration is fixed.

3) AZ-2 looks at the voltage at the top of Rx for 40 ms. This is defined as the zero level for signal measurement and is stored in A/D.

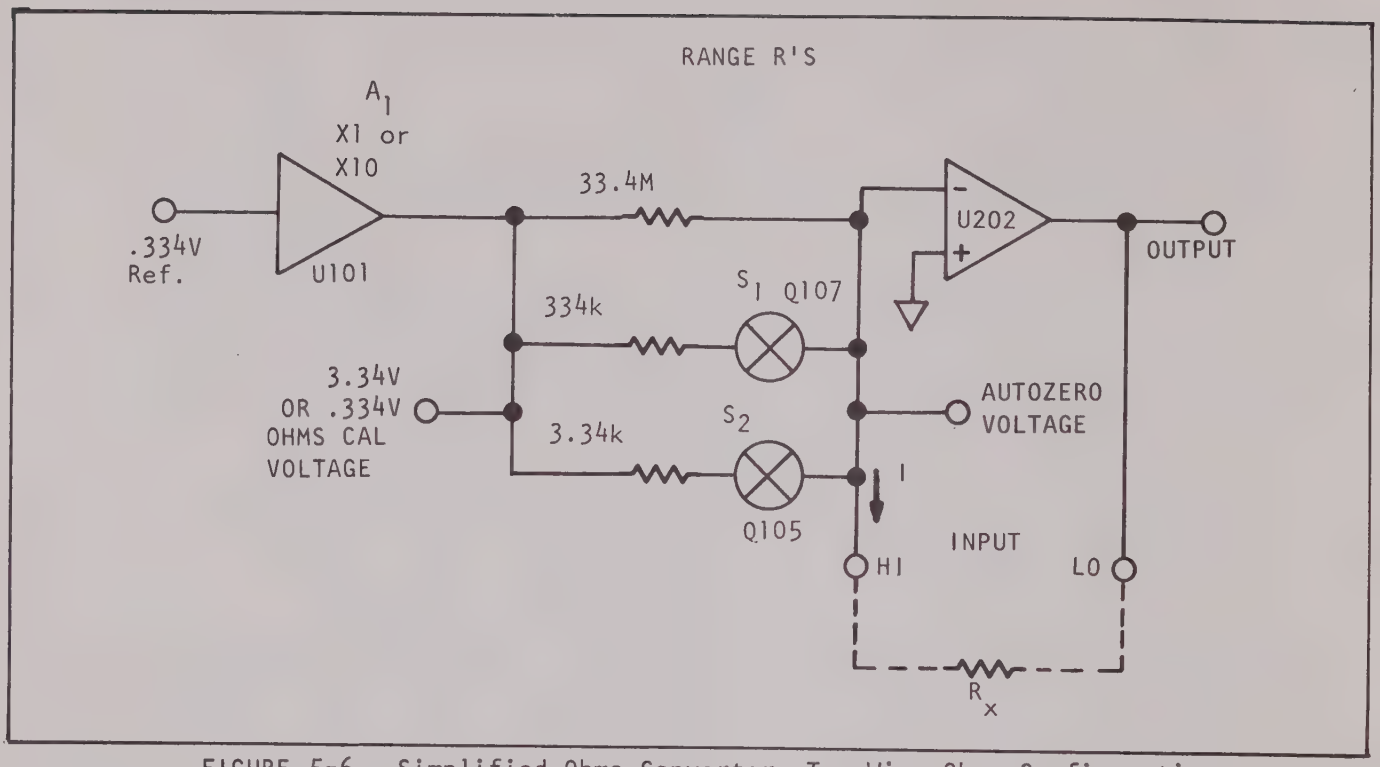


FIGURE 5-6. Simplified Ohms Converter, Two-Wire Ohms Configuration.

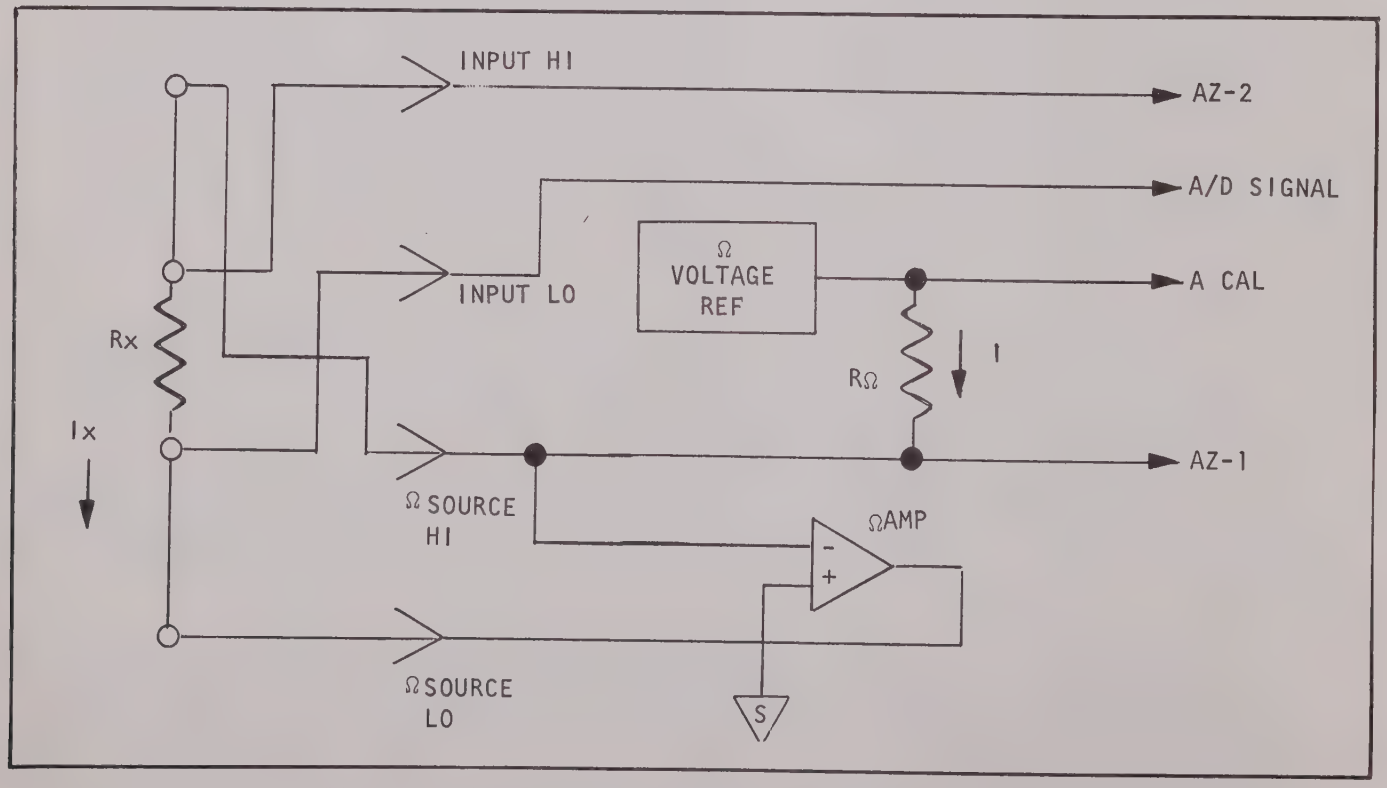


FIGURE 5-7. Four-Wire Ohms Measuring Technique.

4) A/D Signal looks at the bottom of Rx for 200 milliseconds. The A/D thus measures the difference between A/D Signal and AZ-2 without polarity sign. The voltage across Rx is displayed.

c. The measurement is essentially a ratio measurement between the voltage across Rx and the voltage across RΩ.

d. Note that the voltage at the top of Rx is essentially at signal LO of the instrument (± ΩAMP offset and lead resistance drop) and the voltage at the bottom of Rx is negative. Thus, the high impedance terminal is guarded and relative fast response is achieved at high resistance values.

5) Refer to sheet 1 of Schematic 29145E for the remainder of the ohms converter circuit discussion. The ohms switching FET Q110 is driven by the C-line, Q105 is driven from the A-line and Q107 is driven from the B-line. These lines are also used and decoded to operate the Model 4004 autoranging current. When on, Q110 switches the gain of U101 from one to ten. Q105 and Q107 switch-in the range resistors. Each resistor consists of an adjustment potentiometer, a fixed resistor and the on resistance of a FET (no FET for 33.4MΩ). Amplifier U202 is a FET input amplifier. This amplifier is overload protected by Q106 base emitter junction connected to signal ground, and Q108 base emitter junction connected through Q109 clamp transistor. Thus, the input swing is clamped. Very large voltage excursions on the output side of U202 are allowed (by action of Q205 and CR205. Under normal operating conditions Q205 is operated in the saturated mode. However, under overload conditions, Q205 becomes a current source with its collector to emitter breakdown handling large voltage excursions when signals are positive with respect to the ohms source high. Conversely, if signals are negative with respect to ohms source high, CR205 reverse biases, cutting off that portion of the circuit. All of these high voltages will cause current to flow through R205 (120KΩ) which is connected to the +15 volt supply. The maximum limitation of 250 volts rms is a function of the power rating of R205 (a 1/2-watt resistor), and Q205's 400 volt breakdown.

TABLE 5-4.
OHMS RANGES

RANGE HIΩ	RANGE LOΩ	RANGE R	REF V_1	OHMS CURRENT	RANGE LINES A	B	C
3K	300Ω	3.34K	3.34V	1 mA	+8V	-12V	+8V
30K	3K	3.34K	.334V	100μA	+8V	-12V	-12V
300K	30K	334 K	3.34V	10μA	-12V	+8V	+8V
3M	300K	334 K	.334V	1μA	-12V	+8V	-12V
30M	3M	33.4M	3.34V	100nA	-12V	-12V	+8V
300M	30M	33.4M	.334V	10nA	-12V	-12V	-12V

g. Clamp Circuit (Figure 5-8).

1) The clamp prevents damage to the input circuitry of the A/D converter and the active filter by limiting the maximum input voltage to approximately plus and minus 5 volts. It also functions in conjunction with the 150 Kohm resistor (R217) and 0.01μF capacitor (C209) in the dc attenuator to eliminate any relay arcing whenever high voltage inputs are applied to the instrument during range switching. Low leakage FETS are used to minimize leakage current.

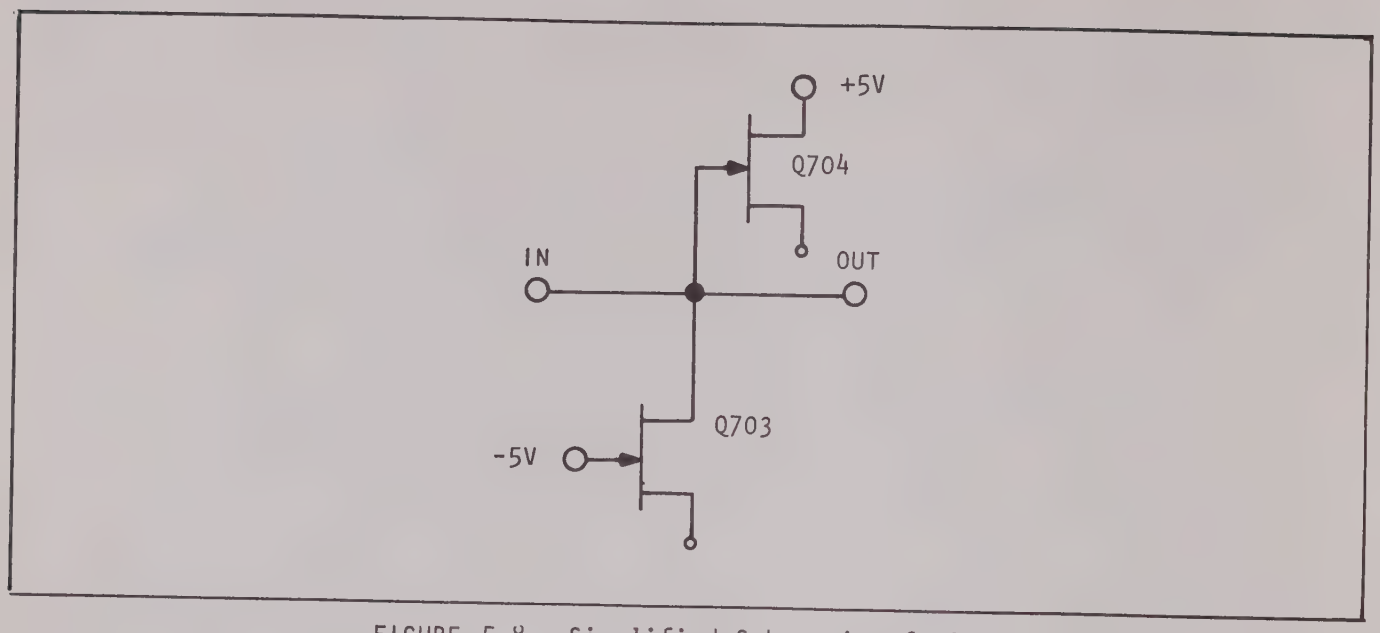


FIGURE 5-8. Simplified Schematic of Clamp.

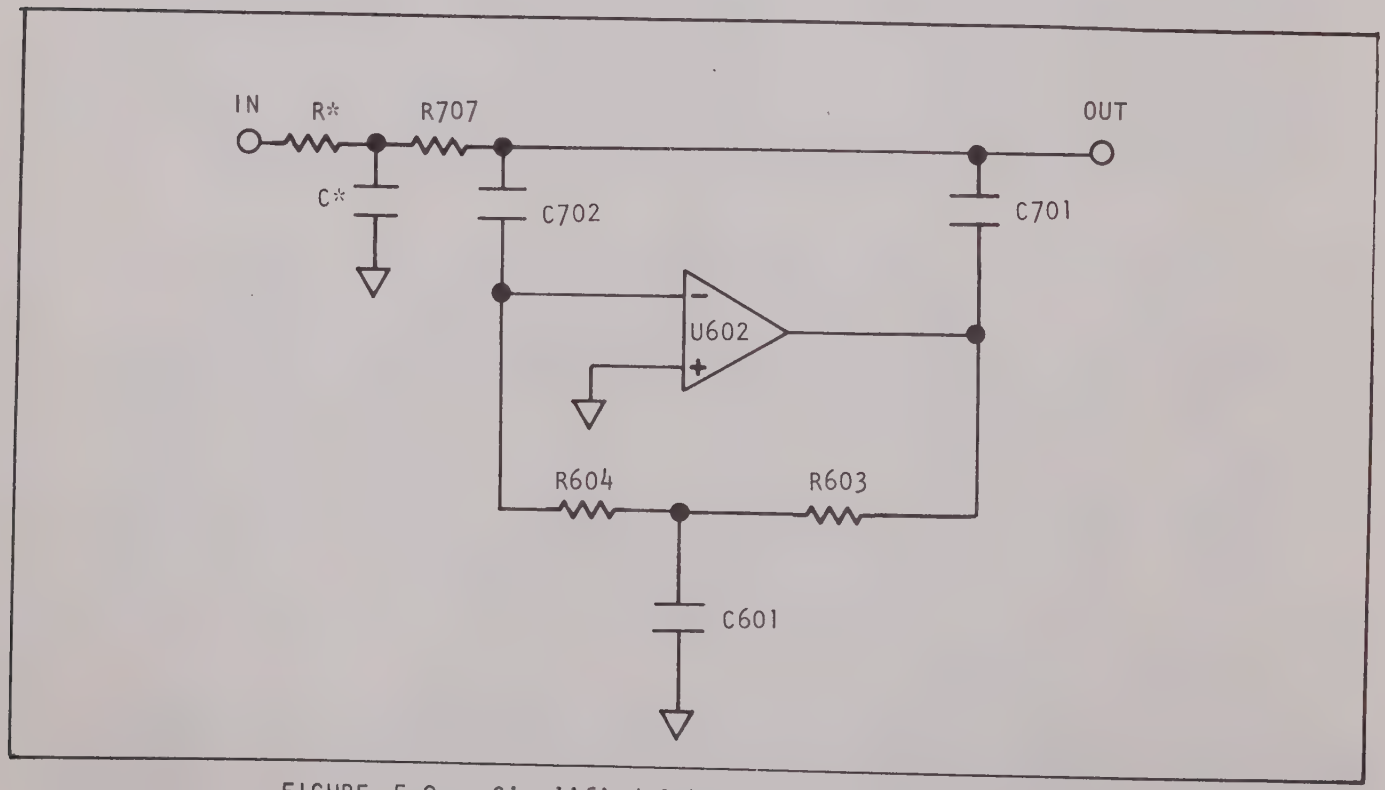


FIGURE 5-9. Simplified Schematic of Active Filter.

2) As shown on Sheet 1 of Schematic 29145E, the -5volts is supplied to Q703 by zener diode VR701 and resistor R710, which is connected to -15 volts.

h. Active Filter (Figure 5-9).

1) The DC filter is used in front of the A/D converter on all functions. The component values used in the circuit provide 250:1 attenuation to 50 Hz on dc volts, and 1700:1 filtering on ac volts output at 50 Hz. Minimum rise time is achieved without overshoot by having the following component relationships: C702 = C701, R604 = R603, R* + R707 = 1.5 (R603) and C702 = 1.5 (C601). The filter requires an input resistance of 200KΩ, 49.9KΩ of which is R707. The other 150KΩ comes from various sources, dependent upon range and function, as given in Table 5-5. The 200KΩ is also maintained so that the effect of A/D converter input current is autozeroed out (see A/D converter discussion, Paragraph 5-4). The filter does not contribute any dc offsets to the signal path. They are blocked by C702 and C701. C903 (not shown) provides frequency compensation for U602.

TABLE 5-5.
Active Filter Input Components.

FUNCTION	RANGE	FIGURE 5-10 C*	FIGURE 5-10 R*
DCV	300mV, 3V		R217
	30V, 300V		R213, R209, R215B, R208
	1200V		R213, R209, 214, R215B, R215C, R208, Q206
ACV	ALL	C102	R106
Ω	ALL		R704

i. Range Selection. Ranging is accomplished by RSA & RSB lines going to LSI circuit U901. They are controlled by the front panel switches AUTO/MAN, DN & UP, according to Table 5-6. RSA & RSB are edge sensitive, causing range changes when their levels are changed. This causes one uprange or one downrange per button push.

TABLE 5-6.
Range Selection.

Range Switches AUTO/MAN	DN	UP	Range Lines RSA	RSB	ACTION
OUT	X	X	0V	+8V	AUTORANGE
IN	OUT	OUT	0V	0V	HOLDRANGE
IN	IN	OUT	+8V	0V	DOWNRANGE
IN	OUT	IN	+8V	+8V	UPRANGE
X = DON'T CARE					

j. Function Switching.

TABLE 5-7.
Function Selection.

FUNCTION	V	FUNCTION SWITCHES DC/AC	A	Ω	HI/LO	Ω	FUNCTION LINES (U901) AC/DC	VI
DCV	IN	OUT	OUT	OUT	X	+8V	+8V	+8V
DCI	IN	OUT	IN	OUT	X	+8V	+8V	+8V (172A) 0V (173A)
ACV	OUT	IN	OUT	OUT	X	+8V	0V	+8V
ACI	OUT	IN	IN	OUT	X	+8V	0V	+8V (172A) 0V (173A)
HIΩ	OUT	OUT	X	IN	OUT	0V	0V	+8V
LOΩ	OUT	OUT	X	IN	IN	0V	+8V	+8V
X ≡ DON'T CARE								

Function selection is accomplished by connecting function lines Ω, AC/DC, & VI according to Table 5-7. The function lines are level sensitive.

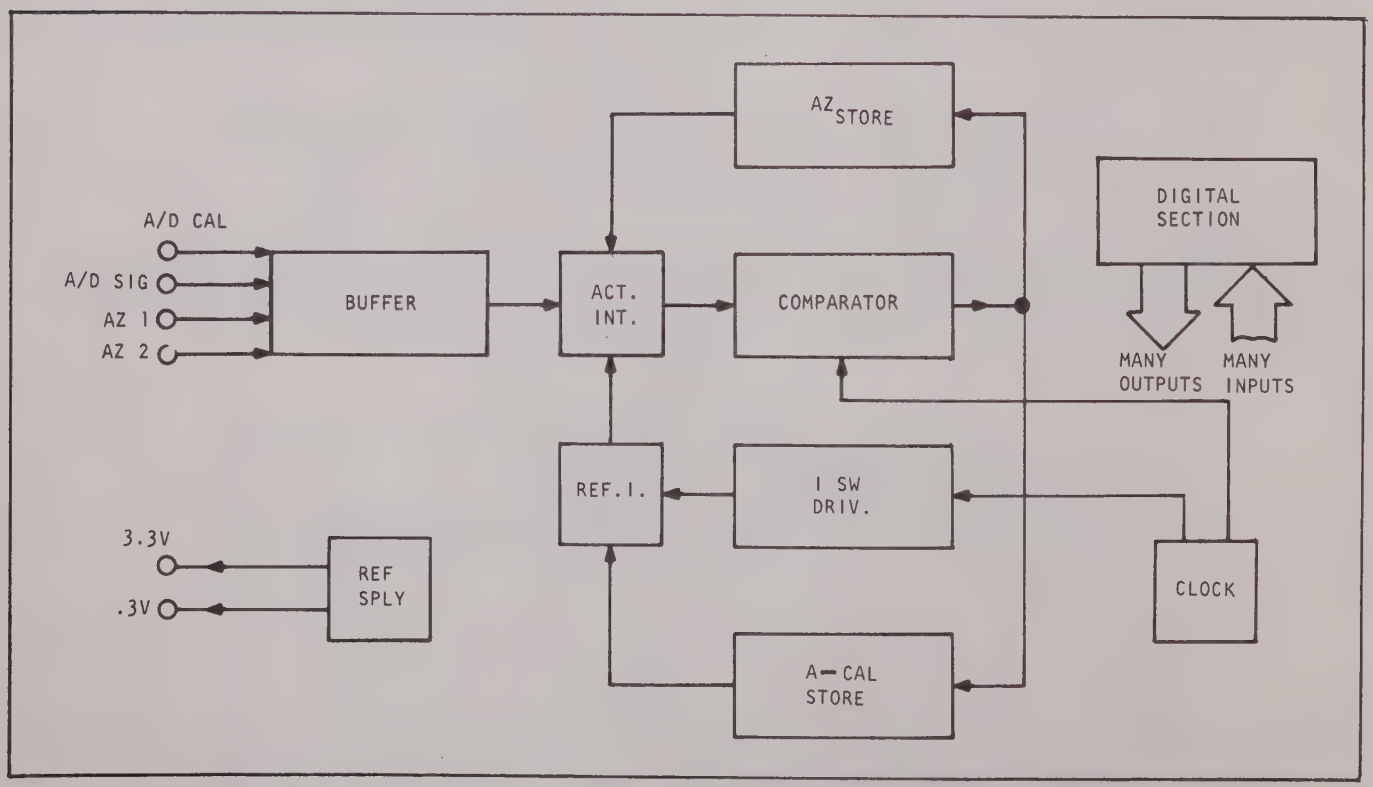


FIGURE 5-10. Simplified Block Diagram of A/D Converter.

5-4. A/D CONVERTER AND DIGITAL CIRCUITS. (Schematic 29145E, Sheet 2).

a. Introduction. A simplified block diagram of the A/D Converter and Digital Circuits is shown in Figure 5-10. The A/D converter generates a digital pulse train which over a specified time period is directly proportional to the dc voltage applied. It has the capability to measure its own offsets and gain errors as well as those of circuitry in front of it (i.e., ac/dc converter, dc attenuator and ohms converter). The converter then cancels the effect of these errors by storing appropriate correction voltages in auto-zero and auto-calibrate storage. A conversion cycle consists of four different operating modes, as shown in Figure 5-11. During each mode, a different input is connected to the A/D buffer. The difference voltage between ACAL and AZ-1 is the calibration voltage, while the difference between signal integrate and AZ-2 is the measured voltage. The converter uses the charge balancing conversion technique, and polarity detection is accomplished digitally. Almost all of the digital tasks are handled by a custom large scale integration (LSI) circuit. Note: details of the operation of the LSI chip will not be given in the A/D converter discussion. However, various of its outputs which are necessary for the operation of the remainder of the A/D converter will be referred to when necessary.

b. Charge-Balancing Technique. The charge-balancing converter of the Model 4004 DMM is built around an active integrating circuit and a comparator circuit which at first glance may appear similar to a dual-slope converter. However, its operation is quite different. In the charge balance converter, the net charge for an integrating cycle (charge/discharge cycle) is zero, and the digital output from the converter is a function of the number of integrating cycles that occur during the measurement conversion period (signal integrate). The number of integrating cycles in turn, depend upon the level of the input signal. In the Model 4004 DMM , the input to the A/D converter is offset to handle bipolar input signals and the number of integrating cycles (output counts) increases as the input voltage increases in the positive direction. For example: on the 3VDC range, a -3 volt input would produce zero counts, zero volts (30,000 counts) and +3V (60,000 counts). It can be seen from the example that a minus sign would have to be displayed from 0 to 30,000 counts and that 30,000 counts would have to be subtracted in order to display zero with a zero volt input. Both of these tasks are handled by the digital circuits.

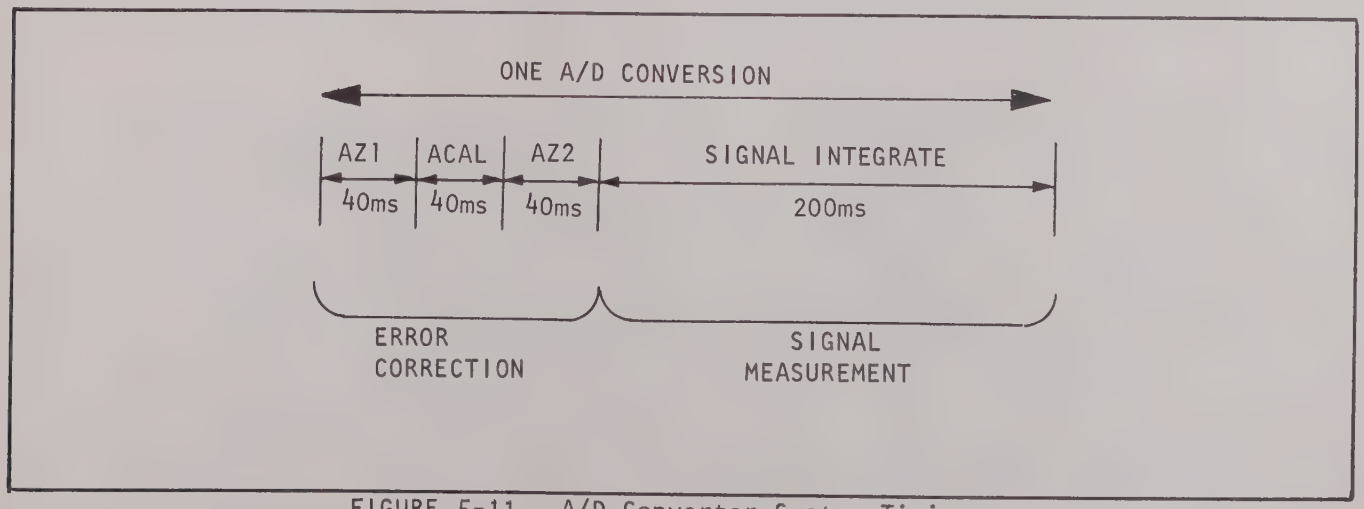


FIGURE 5-11. A/D Converter System Timing.

c. Basic Operation of the A/D Converter. The four basic operating modes of the A/D converter are described as follows:

1) AZ-1. The buffer input is connected to reference low (signal LO in V and A functions), or summing junction of the ohms amplifier in Ω function. The switching rate for zero input is forced into the current switch drivers. The comparator output applies a dc correction voltage to auto-zero storage. This voltage is stored and applied to the active integrator forming a negative feedback loop which quickly stabilizes.

2) Auto-Calibrate. In this mode, the buffer input is connected to the reference (3.3444 Vdc in V and A functions, or the ohms reference in Ω). Auto-zero storage continues to apply AZ-1 correction voltage to the active integrator. The current switch drivers are forced to switch at the appropriate rate for reference input, and a dc correction voltage from the comparator is applied to auto-cal storage. This correction voltage is stored and continually applied to the reference current source which changes the reference current removed from the active integrator, completing another negative feedback loop.

3) AZ-2. The same procedure as AZ-1 is followed, with the exception that the buffer is connected to input LO (zero circuit for dc V and A functions, ac/dc converter for ac V and A, or input HI for Ω).

4) Signal Integrate. The buffer is connected to signal input (dc attenuator output for dc V and A, ac/dc converter output in ac V and A, or input LO in Ω). AZ-2 and ACAL voltages are still applied, which provide compensation for zero and gain errors. The A/D conversion is now made, and displayed during the next conversion cycle.

d. A/D Buffer. The buffer (shown in Simplified Schematic, Figure 5-12) performs two functions. It has four multiplexing JFET switches (S1 through S4) that connect the necessary inputs to the A/D converter to provide the four basic modes of operation. The driving signals (Z_1, Z_2, R and NS) for the multiplexing switches come from LSI circuit U901. The second function of the buffer is to provide two gains (x1 and x10) which give 3V and 0.3V ranges, respectively. Buffer gain during AZ-1 and ACAL is x1 for V, A and every other Ω range. Buffer gain during AZ-2 is the same as signal integrate on all current ranges of the DMM. A gain of x1 is used elsewhere. LSI chip U901 controls S5 and S6 (Q702 and Q701) via the G10 line.

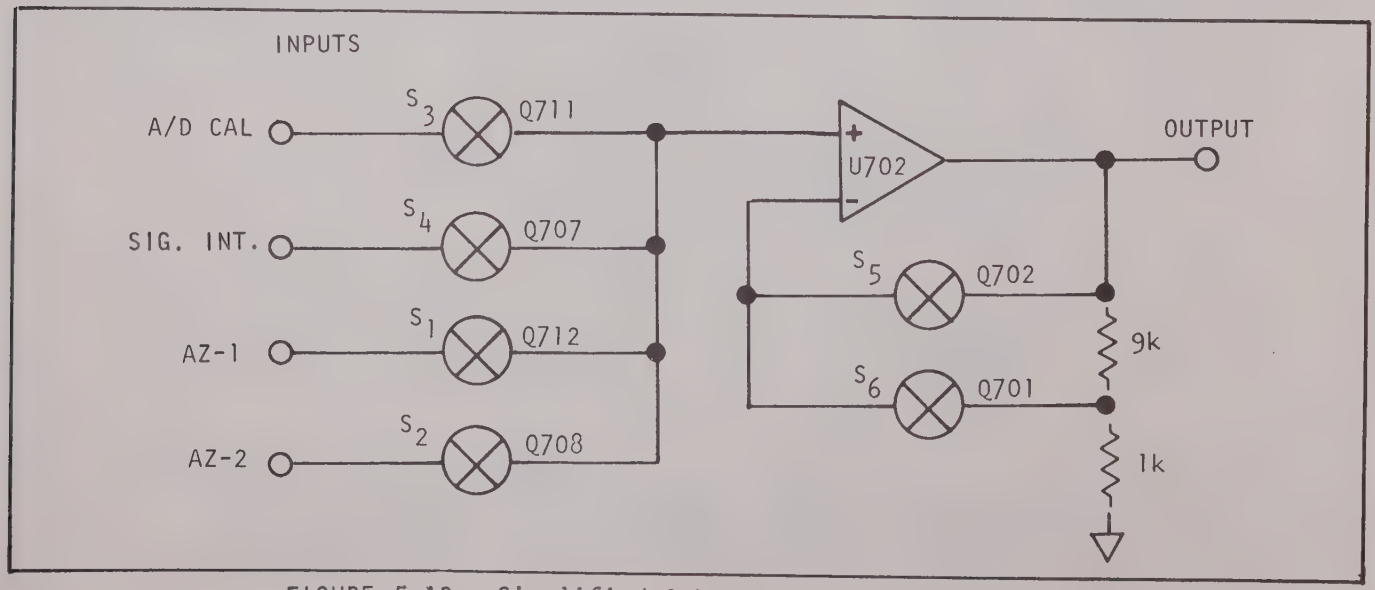


FIGURE 5-12. Simplified Schematic of A/D Buffer.

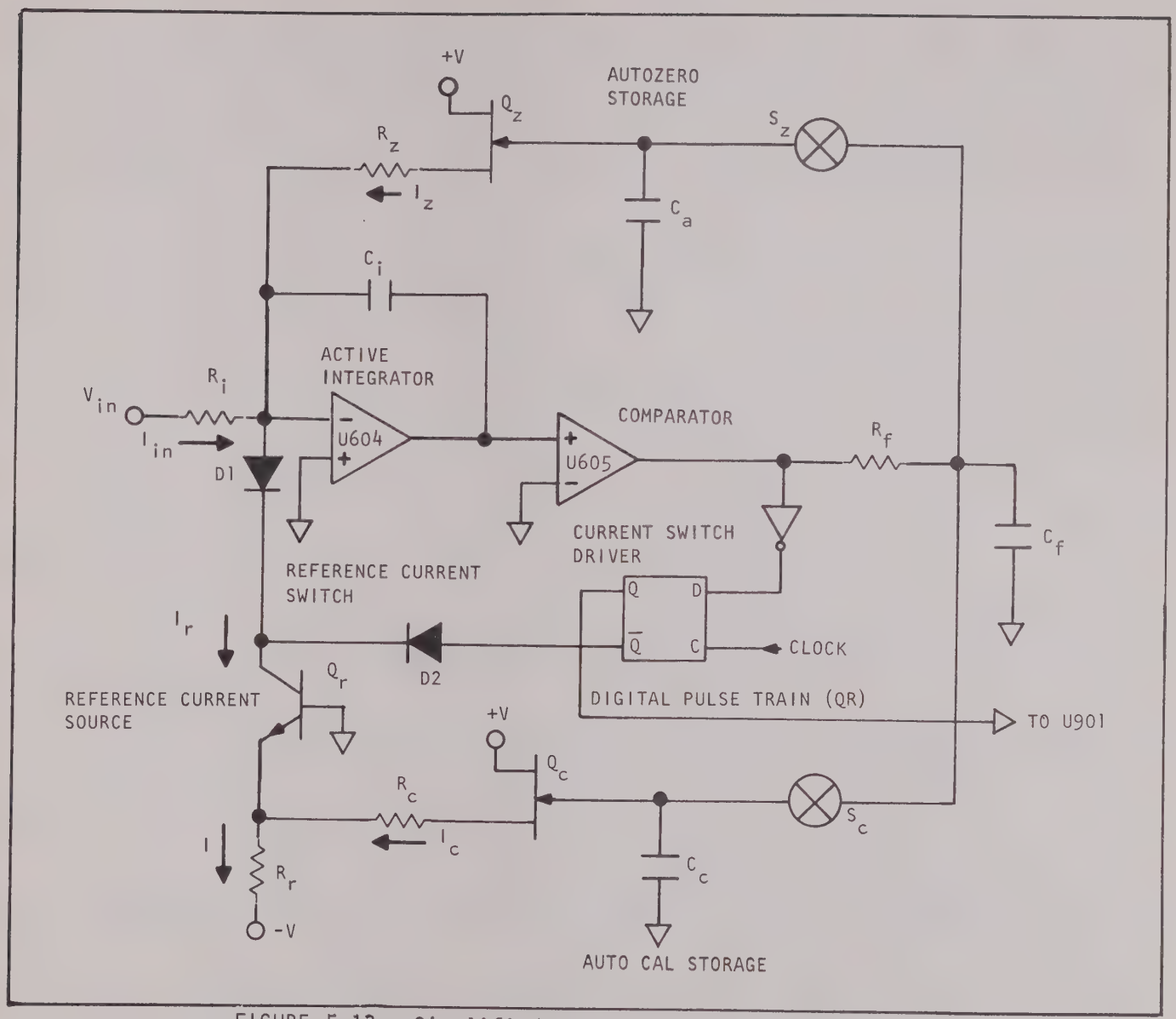


FIGURE 5-13. Simplified Schematic of the A/D Converter.

e. A/D Converter Simplified Schematic Description (Figure 5-13).

1) The active integrator, reference current switch and driver, comparator, AZ and ACAL storage circuits are shown on the simplified schematic diagram. After the buffer, the A/D converter becomes unipolar, using only one reference current. Since bipolar inputs are applied to R_i, the nominal value of I_z is such that if Vin = -3 volts, $I_z - I_{in} \geq 0$. Thus, -3 volts is zero counts, 0 volts is 30,000 counts and +3 volts is 60,000 counts. The LSI circuit (U901) counts in this way, providing digital polarity sensing. It should be noted that a 60,000 count span is used as described above, with the exception that it is shifted up from zero count to center on the approximate 66,900 counts produced by the clock during signal integrate. This is done so that LSI circuit can detect overrange conditions in both polarities and to permit a signal settling time, after connecting it to the buffer, before beginning the conversion.

2) Charge balance A/D conversion is used. With this conversion method, the resulting output pulse train has the property that its average frequency over a given time period is proportional to the average of the input voltage over the same time period. Thus, the digital output is a representation of the true integral of the analog input over any specificed sampling time. The basic converter consists of the active integrator, comparator, current switch driver, reference current switch and the reference current source. For this description, assume that the charge on the integrating capacitor (c_i) is such that the output of U604 is initially at some positive level. As the input signal current (I_{in}) is integrated by the capacitor, the output of U605 ramps negative and eventually becomes more negative than the comparator threshold. The comparator output goes to logic zero, which is inverted to logic 1 by the inverter and applied to the "D" input of the flip flop. At the next positive going edge of the Clock, this "one" is latched by the flip flop and appears as the set output QR, and the $\overline{Q}$ output of the flip flop turns on the current switch. The reference current I_r is forced to flow out of the integrating capacitor, discharging it, and the output of U604 crosses the comparator threshold in the positive direction. This results in a logic 0 at the "D" input of the flip flop and the next positive going edge of the CLOCK signal resets the flip flop, which terminates the pulse on the QR line and turns off the current switch. The converter will remain in this state until the next time that the integrator voltage crosses the threshold of the comparator in the negative direction. For relative large values of the input, the time required for the capacitor to be recharged to the point where the comparator threshold is exceeded will be relatively short and the integration cycle (charging - discharging cycle) described will occur at a high frequency. Conversely, with lower values of input current, the charging time of the integrator will be longer and the events described will occur at a lower rate. Thus, the repetition rate of current pulses (and digital output pulses) is a function of input current. It should be noted that the current switch driver circuitry shown has been greatly simplified for this discussion. In actual operation, the current pulse is limited in time to one-half of the output pulse on the QR line, and is turned on and off by a 90° out of phase clock which centers the current pulse on the digital output pulse to eliminate edge problems. Since the amount of current removed from the integrating capacitor during each discharge cycle is equal to the product of I_r and one-half clock period, the current pulses are uniform in size. The total charge removed from the capacitor in any given time period is equal to the total charge that flowed in (within a resolution of one discharge increment). The uniformity of size of the reference current pulse guarantees that the total number of such pulses is proportional to the time-integral of the input current.

3) The auto-zero correction is always applied to the active integrator, but during AZ-1 and AZ-2, the switch S_z is closed which allows correction of the auto-zero signal. The rest of the time it is stored on capacitor C_a. The correction signal is generated by forced switching of the current source at the "zero" input rate. Since the input is offset, this equates to a midscale current input. The correction signal is the dc level developed at the output of the comparator by R_f and filtered by C_f. Auto-zero correction is supplied as negative feedback to the integrator input. Auto-zero correction can be considered as a contribution to input current since it affects the charge portion of the integration cycle.

4) The auto-calibrate correction is continually applied to the reference current circuit. S_c is closed during Auto-Cal to update the correction voltage, and is stored on capacitor C_c. Auto-Calibrate correction is generated similiarly to auto-zero correction, with the exception that forced current switching is done at the full-scale current input rate. Auto-calibrate correction varies I_r and thus, sets the amount of charge removed from C_i during the discharge cycle since the source "on" time is fixed at one-half the clock period.

5) In the reference current circuit, the base of Q_r is referenced to ground and the emitter resistor R_2 connects to a negative voltage (-V). The current through R_r (I) is approximately equal to $I_r + I_c$ (neglecting base current of Q_r). Since I is constant, I_r will vary inversely with respect to a change of I_c.

6) The reference current switch consists of two diodes, and is controlled by the current switch driver circuitry. Reference current is removed from the summing junction of the active integrator when D_1 is conducting. When $\overline{Q}$ of the D flip flop is high, D_2 conducts cutting off D_1. The Q output of the flip flop is the digital pulse train proportional to the output. The circuitry which forces predetermined switching rates during AZ-1, AZ-2 and ACAL is not shown.

f. Oscillator. The oscillator (shown in Figure 5-14) is crystal controlled and operates at approximately 669 kHz. It is divided down 2:1 to produce the A/D converter clock. The oscillator runs at twice the clock rate for the following two reasons:

1) It allows the current switch to be on only one-half of the clock period, so that there is always an off time even when the current switch is on for consecutive clock cycles. This eliminates a gross nonlineraty problem from the charge-balance A/D converter.

2) It allows the current to be switched on and off with a 90° phase shifted clock signal (generated by the oscillator) so that there will be no timing problems with the edges of the current pulses.

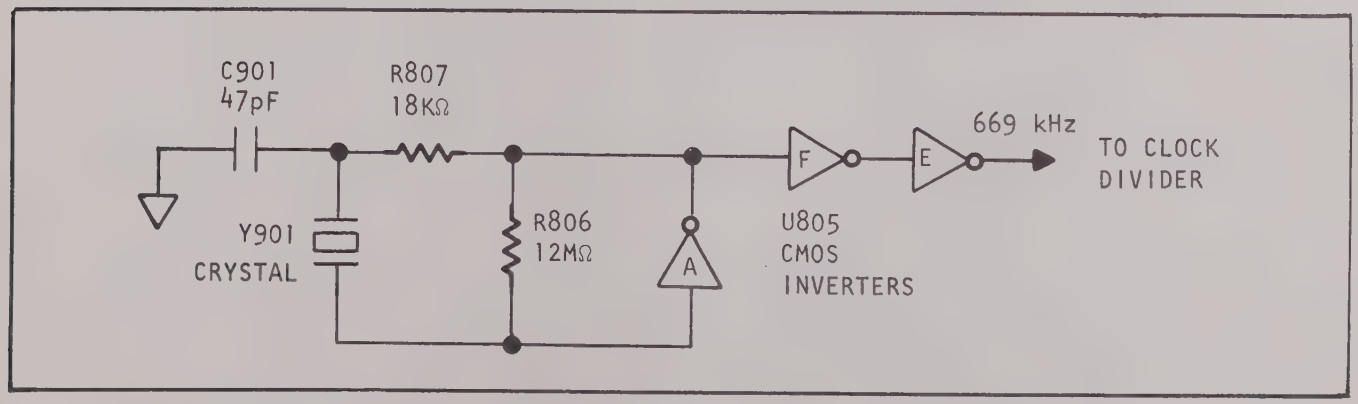


FIGURE 5-14. Simplified Schematic of 669 kHz Oscillator.

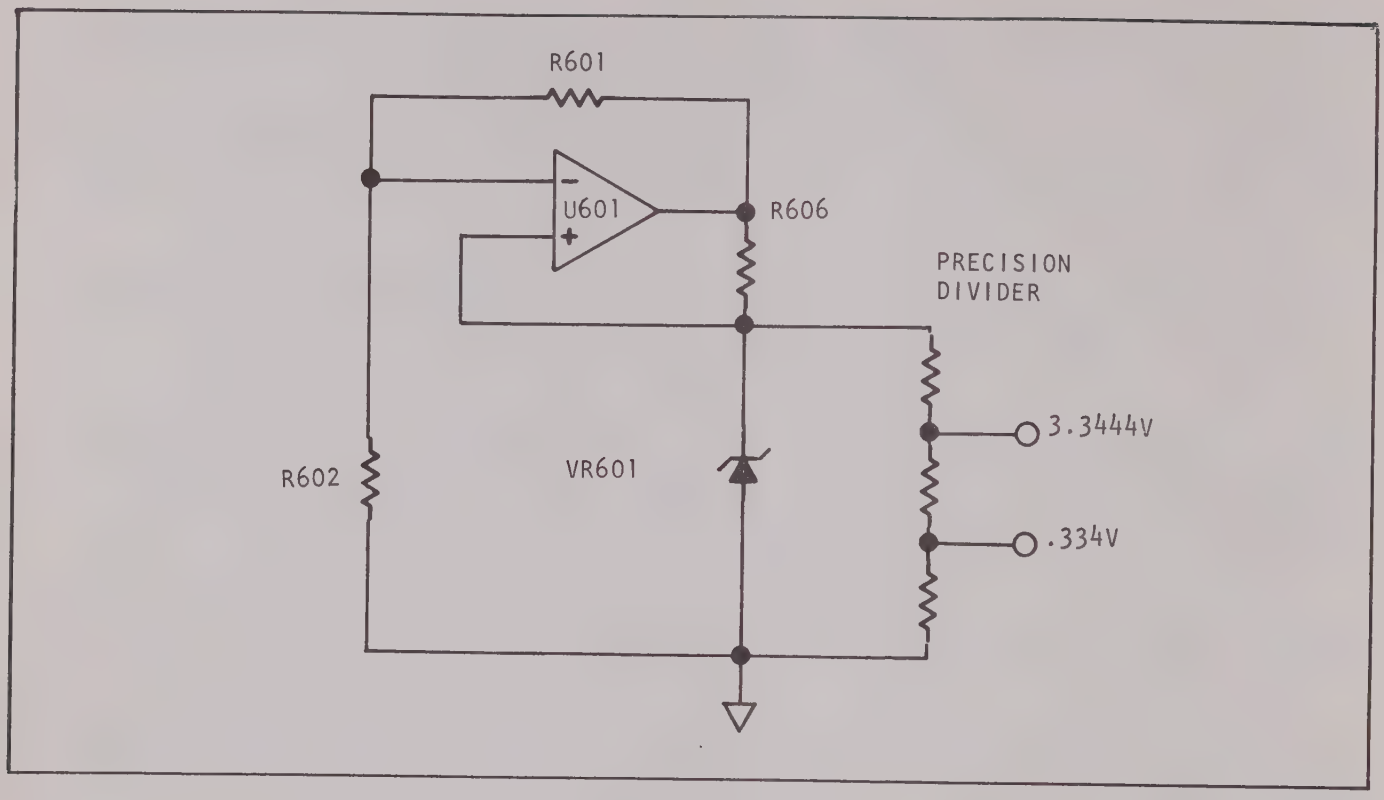


FIGURE 5-15. Simplified Schematic of Reference Supply.

g. Reference Supply. Although not actually a part of the A/D converter circuitry, the reference supply (shown in Figure 5-15) furnishes the stable known voltages required to auto calibrate the A/D converter. These voltages are also used in the ohms converter circuitry. The heart of the reference supply is a stable, low temperature coefficient zener diode. It is driven from a constant current (nominally 7.5mA) developed by amplifier U601. With the zener current well regulated, it is immune to power supply variations. The output divider resistors are part of a precision resistor network which provides very stable reference voltages. R606 and the input resistors of the divider are specially selected (depending on the zener voltage) to provide a nominal 200μA of current to the divider. The zener voltage is between 6.15 and 6.5 volts, with the resistors matched accordingly.

h. Digital Section. The digital section is composed almost entirely of the custom LSI circuit U901. It keeps track of the function and range, allows auto or manual ranging, generates the display information, controls the A/D converter timing, provides ranging lines for the signal conditioning circuitry, and provides information for the optional digital interfaces, as well as controlling them.

5-5. DISPLAY BOARD, SCHEMATIC 27404D.

a. This schematic shows the display digits, the LED function indicators, all display drivers and multiplex timing generator. The entire display, including minus sign and function indicators, is fully multiplexed. This is accomplished with six time slots (timing mux). The mux times are generated by shift register U301 whose inputs come from the LSI circuit (U901, Schematic 29145E). These time slots are referrred to as t_0, t_1, t_2, t_3, t_4, t_5. The common anodes of each digit and the common anodes of the function indicators are driven from the appropriate mux line, see Figure 5-16. These mux times occur in the operating digital interfaces (see Section 5-8, Option 51). This mux times occur in the sequence t_0 thru t_5; t_0 and t_1 are 383 microseconds each, and t_2 thru t_5 are 191 microseconds each. One complete mux cycle is 1.53 milliseconds.

b. The data mux lines, a, b, c, d, e, f, g, and dp drive the cathodes of the display segments and the function indicators. See Table 5-8. The data mux lines are generated in the LSI circuit U901, Sheet 3 of Schematic 29145E.

c. The 10,000 digit only indicates 1, 2, or 3 in overrange. If the 10,000 digit is zero, it is blanked by the data mux lines. It is necessary to operate the function indicator and minus sign twice as long as the digits. Since "AC" and "-" are activated during t_1, the 10,000 digit time, t_1 is as long as t_0. To keep the 10,000 digit the same brightness as the other digits, a, b, c, d, e and g data mux lines for this digit are on for half of t_1 time.

d. The anode driver transistors are saturating switches (Q301 thru Q306). The segment driver transistors are emitter followers (Q307 thru Q314). R302A thru R302H are current limiting resistors. Segment current is approximately 30 milliamperes peak. R303 & C301 decouple current spikes from the 5 volt power supply. C302 decouples U301 from power supply. CR301 and R304 prevent parasitic oscillation of segment driver transistors.

5-6. POWER SUPPLY, SCHEMATIC 29145E. Sheet three of this schematic contains the voltage regulators, line transformer, line voltage switching and power switching for Model 4004 DMM . There are four separate integrated circuit voltage regulators used. VR003 provides the regulated +15 volts and the -15 volt regulator is VR002. These two regulators deliver the ±15 volts used by most of the circuitry in the 4004 DMM. In addition, the regulated +15 volts is supplied to the input of the +8 volt regulator (VR004) and the regulated -15 volts is supplied to Zener diode VR801 via R801 to develop -12 volts. Both of these voltages (+8 and -12) are fed to the LSI chip (U901). The -12 volts is also fed direct to the Switch Driver circuitry and the +8 volts is fed indirectly to this circuitry by the pullup resistors associated with U901. The two 15 volt regulators receive either ±29.5 volts (unregulated) from the line transformer (T001) and full-wave rectifier (CR001), or ±19.2 volts from the batteries in the Option 06 Battery Pack. The unregulated voltages are higher than the regulators need because they are used to recharge the battery pack. If the instrument is off, but the line cord powered, unregulated voltages are fed direct to the Battery pack connectors (P401, 402). There is also a +5 volt regulator (VR001). This regulator is used to drive the display, the digital logic circuitry in the A/D converter, and all relays. This +5 volts is also used to drive the Optical Isolator circuitry whenever the Option 51/SST Interface is installed.

If an Option 06 battery pack is installed in the Model 4004 DMM the batteries of the Option 06 will be charged through the unregulated voltages. When the instrument is line powered, resistors, R005, R006 and R007 feed the charge inputs on the battery pack. These resistors drop the charging current down to the trickle charge level. As previously mentioned, the 8 volt regulator, VR004, gets its input from the regulated +15 volt output of VR003. The input for VR001 (5V regulator) is derived from transformer secondary 7 and 8, full-wave rectifier CR002 and R003. This unregulated +14.5

TABLE 5-8.
Display Data MUX Lines.

8 LINES	DRIVES DISPLAY SEGMENT OF INDICATOR LIGHT DURING					
	t_5	t_4	t_3	t_2	t_1	t_0
a	a	a	a	a	a for last ½ of t_1, Off other half	mV indicator
b	b	b	b	b	b for last ½ of t_1, Off other half.	V indicator
c	c	c	c	c	c Same as above.	µA indicator
d	d	d	d	d	d Same as above.	mA indicator
e	e	e	e	e	e Same as above.	A indicator
f	f	f	f	f	AC indicator all of t_1	Ω indicator
g	g	g	g	g	g for last ½ of t_1 Off other half	kΩ indicator
dp	dp	dp	dp	dp	"-" indicator All of t_1	MΩ indicator

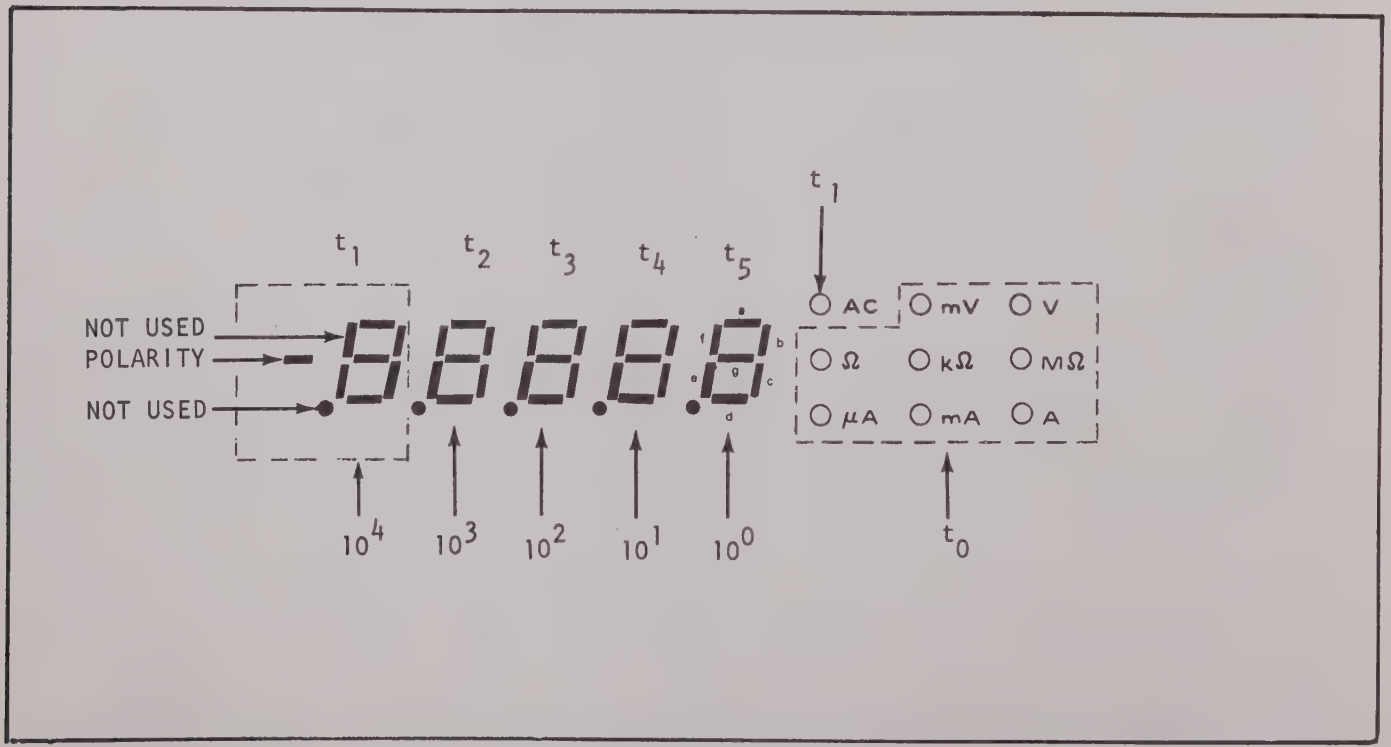


FIGURE 5-16. Digital Display Multiplex Scheme.

also charges the 8.4V batteries. In BAT mode, the ±19.2 volts and the +8.4 volts from the batteries connect to the input terminals of VR002, VR003 and VR001. The line switch applies ac voltage from the transformer to the Option 51 for its regulated 5 volt supply. Thus, turning the DMM off also turns off the Option.

Transformer T001 has two internal shields, one secondary shield tied to pin 10, and one primary shield tied to power ground. This shielding provides line isolation. When the dual primary of T001 is tied in parallel by switch S001, the Model 4004 DMM is connected for 117 volt operation. Switch S001 also puts these primaries in series, for 230 volt operation, as indicated on the schematic. Provision for 100 volt line is interchanging connections 5 and 6 and connections 2 and 3 on the primaries. This is a physical wiring change that must be made on the printed circuit board, and is a factory option.

There are two connectors for the Option 06 battery pack, P402 and P401. The self-check terminals are on the bottom of the instrument. There is an "ac" self-check, "dc" self-check and an "ohms" self-check. Connect from the appropriate self-check terminal to the input high terminal to exercise the instrument. The self-check is not accurate, the voltages and currents are only approximate. A battery test point ("A") on the bottom of the instrument allows checking the + 19.2 volt battery of the Option 06. Normally the low battery light will indicate when the batteries have become low and need recharging. However, the test point could be used to troubleshoot for a defective cell.

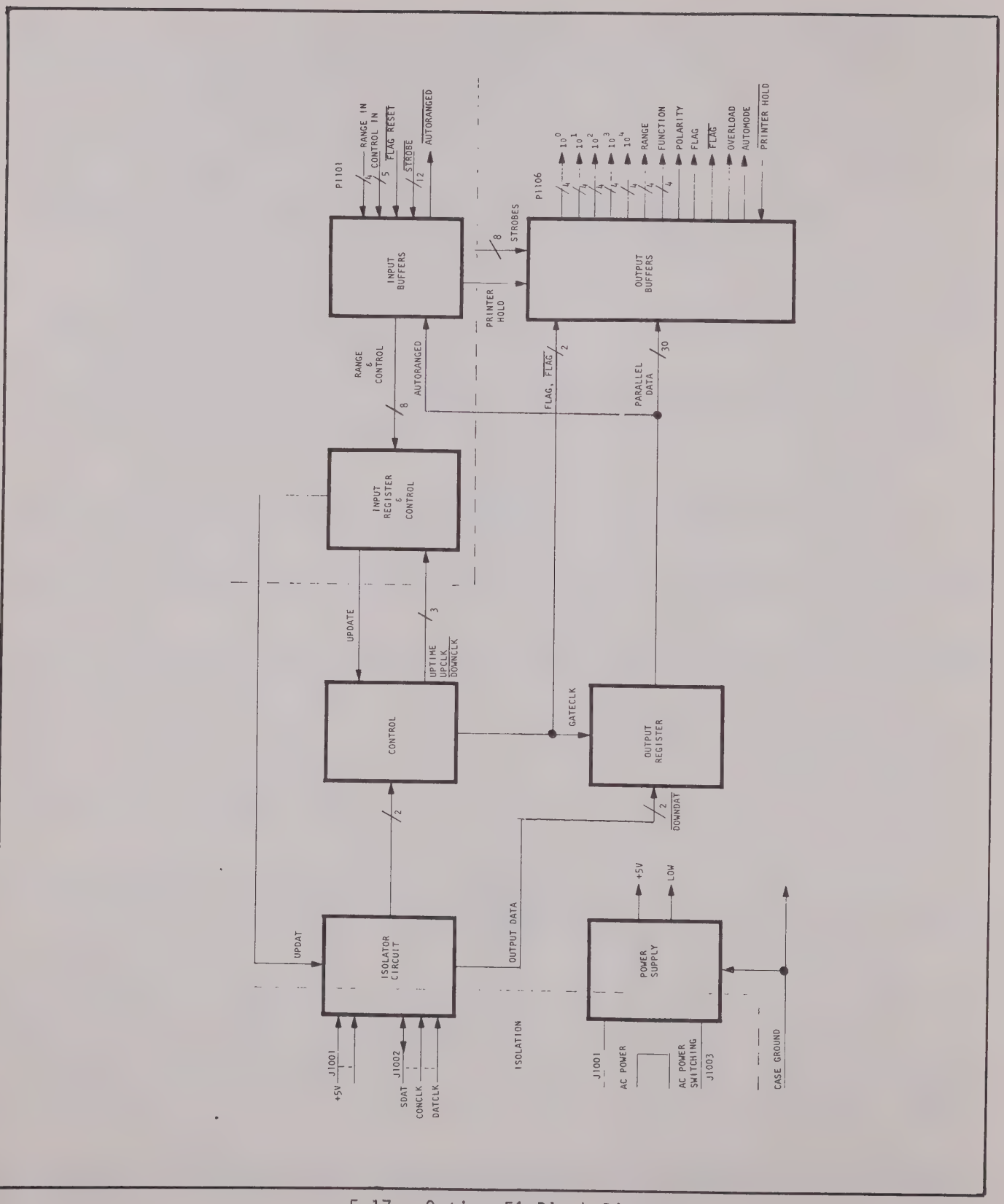
5-7. OPTION 06 RECHARGEABLE BATTERY PACK, SCHEMATIC 26758C. The Option 06 provides ±19.2 volts and +8.4 volts from nickel-cadmium batteries. BT401 and BT402 are 19.2 volt, .45 AH nickel cadmium packs which are fused by 1A, 3AG Slo-Blo fuses. BT403 is an 8.4V pack composed of seven 1.2 volt "C" cells and is also fused by a 1A, 3AG, Slo-Blo fuse. The Option 06 has a built-in recharging circuit which operates from ±29.5V (unregulated) supplied by the DMM line-power supply.

a. BT401 Charging. BT401 is charged via a constant current from Q401. Diodes CR401 and CR402 and resistor R402 place a diode drop across R401. The resulting current is the maximum charging current. Diode CR403 prevents the battery from supplying current through Q401. The maximum charging current occurs only when the DMM is set to OFF. A trickle charge is maintained when the DMM is line operated. The reduced current is obtained by inserting a limiting resistor in series with the charging circuit (not shown on Schematic 26758C). In full charge, the batteries are charged at a C/10 rate (45 mA for BR401 & BT402, & 200mA for BT403). When trickle charged, the charge rate varies according to line voltage & battery condition from a minimum of C/100 rate to a maximum of C/20 rate. Thus, trickle charge may never fully charge the batteries, but is intended to put sufficient charge into them for short intermittent use.

b. BT402 & BT403 Charging. BT402 & BT403 are charged via constant currents from Q402 or Q403, respectively. These circuits operate similarly to the above circuit, except that they are powered by unregulated ±29.5V.

c. Low Battery Detector. This circuit monitors the voltage of all three batteries in the Option 06, and provides a drive signal to turn on the front panel low battery indicator if either battery's voltage drops below a predetermined level. The approximate levels are: BT403 (+7.2V), BT401 (17.1V) and BT402 (-17.V). These levels were selected to ensure that a low battery indication will be given before operation of the associated regulator circuits in the DMM can be adversely affected. The heart of the detector circuit is U401, which is connected as an open-loop comparator. Low voltage detection for each battery is described as follows:

1) BT403. The threshold of the comparator is set at approximately +7.2 volts by a divider consisting of R407 and R410 connected between the regulated +15 volts and



5-17. Option 51 Block Diagram

common. BT403 is connected to the inverting input of U401 through fuse F403 and resistor R408. When the voltage of BT403 drops below the comparator threshold, the comparator output switches positive, turning on the low battery indicator.

2) BT402. For detecting a low voltage condition of BT402, a divider consisting of R411 and R412, and a NPN transistor (Q404) is used along with the comparator. The emitter of Q404 is connected to the regulated -15 volts, and its base level is set by the divider connected between common and BT402 through fuse F402. With the voltage of BT402 at -19.2 volts, the base-emitter junction of Q404 is reverse biased by approximately 1 volt. When the voltage drops below approximately -17.1 volts, Q404 is turned on, dropping the inverting input of U401 below the threshold voltage and the low battery indicator is turned on by the output of U401.

3) BT401. Low voltage detection of BT401 is similar to that described for BT402, with the exception that when Q405 is turned on the threshold voltage of U401 is raised above the +8.4 volts supplied by BT401. The result is the same. The output of U401 switches positive, turning on the low battery indicator.

4) It should be noted that the switching levels described above can vary slightly, because of the ±5% tolerance of the regulated power supplies in the DMM.

5-8. OPTION 51 DIGITAL INTERFACE .

a. Overall Block Diagram. As shown in Figure 5-17, Serial data from the DMM and its associated clock lines are first isolated. Bidirectional data line SERDAT is then split. Output data DOWNDAT goes to the output register block where it is converted to parallel form and then to the output buffers. The clock lines go to the control block which decides where the data is going, out or in, and also generates the flag. Control input data and strobes are first buffered by the input buffer block. The strobes go to the output buffer to gate the outputs. The control, data inputs go to the input register and control block where they are converted from parallel to serial form and sent to the isolation block. The input register and control block also decides, based on control data input, whether there is to be an output update. Power isolation for Option 51 is provided by transformer T1001 which is powered by a secondary winding of the DMM power transformer.

b. Signal Isolation. (See Schematic 27902E). The bidirectional data line (SERDAT) and the two clock lines (SERCLK and INCLK), each drive an emitter follower (Q1035, Q1037 or Q1036) whose load is an LED in its respective opto-isolator (U1019, U1021 and U1020). The outputs of these opto-isolators are pulled up by R1009, R1012 and R1010, respectively. U1018 is driven by Q1034 in a similar manner to the three opto-isolators just mentioned, and its output pullup is on the DMM mainframe.

c. Power Supply. Low voltage ac from the secondary of the DMM transformer is supplied via pins B and C on J1001. Switching for the power for T1001, provided at J1003 Pins A and B, comes via the DMM mainframe through its Power ON switch. The secondary of T1001 is rectified, filtered and run through an integrated circuit (+5V regulator TR1001) whose output is filtered by C1015, C1002, C1003, C1004, C1014. The core of T1001 is connected to chassis ground by a green wire to a screw on the DMM mainframe or transformer. Also common mode filtering is performed by R1008 and C1006 connected between output low and chassis ground.

d. Control Block. UPCLK, the isolated form of INCLK, is run to the trigger input of E1017 timer. A buffered version of UPCLK is also run via diode gate CR1002 to the threshhold input of U1017. U1017 is such that its output will go high when a falling edge goes into trigger. A filter made up of R1007 and C1008 will try to charge, however, since this threshhold is clamped low through diode CR1002, it will not be able to time

out in the time period of the clock pulses on INCLK until the last rising edge of INCLK, at which time it will clock out at 30 microseconds. Therefore, UPTIME, the output of U1017, will be length of the INCLK pulse stream plus approximately 30 microseconds. This is the time in which data will be flowing from the Option to the DMM. The beginning of a conversion is started by clocking DOWNCLK with UPTIME in flip-flop U1015A. The beginning of downtime also defines the time when the flag is set high, that is, when data has finished being updated. Setting the flag low during data change time, or re-setting the flag, is accomplished in two ways: FR or UPDATE. Downtime also gates DOWNCLK thru U1014C & U1014D where it is called GATECLK and goes to the output register.

e. Output Register. The output register is made up of shift registers U1008A & B, 1009A & B, 1010A & B, 1011A & B. It is a 32-bit shift register, of which only 30 are used. Serial data enters U1008B and is clocked through all of the shift registers by the parallel clock, GATECLK. At the end of the clocking time all 30 bits have been shifted in and are presented in parallel to the output buffer.

f. Output Drive and Buffer. Parallel data on the output registers goes to output gates U1001 thru 1007 and U1012 and 1013. Here, the data is gated with the output strobes through drive transistors (Q1001 thru 1030) to the output connector P1006.

g. Input Buffers. Strobelines are buffered by U1101 and U1102 and go out to the output drive and buffer block. Remote control inputs are buffered by U1104, U1111, U1105. U1104 is a Schmitt trigger, which is put on certain control lines to prevent false triggering (see Schematic 28019E).

NOTE

Additional information concerning the operation of Option 51 is given in Section 3. This additional information is referenced to three timing diagrams provided in Section 7 (Timing Diagrams: 28247E, 28248E and 28249E).

SECTION 6. MAINTENANCE.

6-1. GENERAL. This section contains information necessary to maintain the instrument. Included are procedures for electrical Performance Verification, Adjustment/Calibration, Troubleshooting, and Fuse Replacement.

6-2. REQUIRED TEST EQUIPMENT. Recommended test equipment for Performance Verification is given in Table 6-1. Test equipment for Adjustment/Calibration is given in Table 6-6. Alternate test equipment may be substituted if specifications equal or exceed the stated characteristics.

TABLE 6-1.
List of Test Equipment for Performance Verification.

ITEM	DESCRIPTION	SPECIFICATION	MFR	MFR MODEL
A	DC Calibrator	±0.2V through ±1000 Vdc ±0.002% or 20μV	FLUKE	332B
B	AC Calibrator	0.2 through 20 v rms ±0.022% + 10μV	HP	745A
C	High Voltage Amplifier (Used with Model 745A)	200V through 1000.0 v rms ±0.04%	HP	746A
D	Decade Resistor	2KΩ through 10MΩ ±0.01%	ESI	DB62
		200MΩ ±0.1%	CADDOCK	MG750
E	Current Source	200μA through 20 mA ±0.006%	FLUKE	3330B
		200mA and 2A ±0.02%	FLUKE	382A
F	Ohmmeter	$10^7\Omega$ ±1% $10^9\Omega$ ±5%	Keithley	616
G	1MΩ Resistor	≥1/8W, ±1% tolerance		

6-3. PERFORMANCE VERIFICATION. Performance Verification should be performed by qualified personnel using accurate and reliable test equipment as given in Table 6-1. Use the following procedures to verify basic operation and accuracy of the instrument. All measurements should be made at an ambient temperature within the range of 20°C to 30°C and with a relative humidity of less than 80%. If the instrument is out of specification at any point, perform a complete calibration as given in Paragraph 6-4. If the instrument is "IN WARRANTY", contact your Racal-Dana representative or the factory.

NOTE

This procedure is intended to verify only the basic accuracy of the Model 4004 DMM in voltage, current, and resistance modes. Test equipment accuracy should be X5 better than the measurement accuracy. In many cases the equipment listed in Table 6-1 is not X5 better, because such equipment is not readily available. For this reason, the expected error contribution of the listed test equipment is

given in the performance verification tables and should be added to the specified accuracy tolerance of the instrument to obtain the allowable readings. The listed "Source Error" assumes that the test equipment has been calibrated to the manufacturer's specifications.

a. Initial Conditions. Before beginning the verification procedure, the instrument must meet the following conditions:

1) If the instrument has been subjected to extremes of temperature, allow internal temperatures to stabilize for one hour minimum at the environmental conditions specified in Paragraph 6-3.

2) Turn on the Model 4004 DMM and allow it to stabilize for one hour. The instrument may be powered from either line power or from battery pack power, as long as the battery pack has been fully charged as described in Paragraph 2-3b.

WARNING

Some procedures require the use of high voltage. Take care to prevent contact with live circuits which could cause electrical shock resulting in severe bodily injury or death.

b. Input Resistance Check. (DC VOLTS).

1) Select DC V function.

2) Select MAN and 3 volt range.

3) Connect the DC Calibrator (A) to the DMM

4) Apply 1 volt dc to the DMM and record the reading.

5) Connect the 1 Megohm resistor (G) between calibrator HI and input HI of the DMM

6) Apply 1 volt dc to the DMM and verify that the displayed reading is within 10 digits of the reading in step 4. This verifies that the input resistance is $>10^9\Omega$.

7) Select the 30 volt DC range using UP RANGE pushbutton.

8) Measure the input resistance between HI and LO using ohmmeter (F).

9) Input resistance should be 10·megohms ±2-1/2%.

c. DC Voltage Accuracy Check.

1) Set to DC Volts and AUTO.

2) Connect the DC Calibrator (A) to the instrument.

3) Set the DC Calibrator to the output specified in Table 6-2.

4) Verify that the instrument reading is within the limits specified.

5) Repeat steps 3) and 4) with negative voltages.

TABLE 6-2.
DC Voltage Performance Check.

RANGE	APPLIED VOLTAGE	NOMINAL DISPLAY	TOLERANCE (SPECIFIED ACCURACY) IN DIGITS**			SOURCE ERROR*
			24 hr, 25 ± 1°C	20 to 30°C 6 mo.	1 year	
300mV	±0.20000Vdc	±200.00mVdc	±3d	±4d	±4d	±2d
3 V	±2.0000Vdc	±2.0000Vdc	±3d	±4d	±4d	±0.4d
30 V	±20.000Vdc	±20.000Vdc	±3d	±4d	±4d	±0.4d
300 V	±200.00Vdc	±200.00Vdc	±3d	±4d	±4d	±0.4d
1000 V	±1000.0Vdc	±1000.0Vdc	±2d	±2d	±3d	±0.2d

* The Manufacturer's specified uncertainty of the DC Calibrator (A). If this calibrator is used, add uncertainty to the 4004 DMM tolerance to obtain the allowable reading. For example, the allowable 1 year 20° to 30°C reading on the 300mV range would be 199.96 to 200.04 with a zero source error. Including the source uncertainty, the reading would be 199.94 to 200.06.

** Tolerances above one half digit have been rounded off to the next higher digit because of the approximate 0.5 digit flash point of the least significant digit of the display.

d. AC Voltage Accuracy Check.

1) Select AC Volts and AUTO.

2) Connect the AC Calibrator (B) to the instrument. Set the calibrator frequency to 20kHz.

3) Apply 200mVac to the instrument. The reading must be within the limits specified in Table 6-3.

4) For the 3 and 30 volt ranges, apply the required voltages stated in Table 6-3 and verify that the readings are within specifications.

5) To check the 300 and 1000 volt ranges, connect the High Voltage Amplifier (c) to the output of the AC Calibrator per the manufacturer's instructions. Connect the amplifier output to the Model 4004 DMM input terminals. Set the calibrator to supply 200.00 Vrms at 20kHz for checking the 300V range, and 1000.0 Vrms at 10kHz to check the 1000V range. Verify that the readings are within the specified limits in Table 6-3.

6) To check accuracy at 50 Hz, apply the voltage specified in Table 6-3 for the 30V range and verify that the reading is within the specified limits.

7) To check accuracy at 100kHz, apply the voltage specified in Table 6-3 for the 200mV range and verify that the reading is within specified limits.

TABLE 6-3.
AC Voltage Performance Check.

RANGE	APPLIED VOLTAGE	NOMINAL DISPLAY	TOLERANCE (SPECIFIED ACCURACY) IN DIGITS 20 to 30°C	SOURCE ERROR*
	@ 20 KHz			
300mV	0.2000 Vrms	200.00	± 46 digits	± 7 digits
3 V	2.0000 Vrms	2.0000	± 46 digits	± 6 digits
30 V	20.000 Vrms	20.000	± 46 digits	± 6 digits
300 V	200.00 Vrms	200.00	± 46 digits	± 8 digits
	@ 10kHz			
1000 V	1000.0 Vrms	1000.0	± 31 digits	± 4 digits
	@ 50Hz			
30 V	20.000 Vrms	20.000	± 220 digits	± 15 digits
	@ 100kHz			
300mV	0.2000 Vrms	200.00	± 220 digits	± 20 digits

* The Manufacturer's specified uncertainty of the AC Calibrator (B). If this calibrator is used, add uncertainty to Tolerance to obtain allowable reading.

e. Resistance Accuracy Check.

1) Select Ω, HI and 2 WIRE.

2) Select AUTO.

3) Connect the Decade Resistor (D) to the instrument input terminals. Set the decade resistor to zero and record the resistance of the test leads. Subtract the lead resistance from the resistance reading on the Model 4004 DMM in the following steps.

4) Set the decade resistor to the resistance values given in Table 6-4. Verify that the readings are within specified limits for HI ohms.

5) Select LO ohms and repeat the decade resistor settings given in Table 6-4. Verify that the readings are within specified limits for LO ohms.

TABLE 6-4.
Resistance Performance Check.

RANGE	RESISTANCE SETTING	NOMINAL DISPLAY	TOLERANCE (SPECIFIED ACCURACY) IN DIGITS 20° to 30°C		SOURCE ERROR*
			HI	LO	
300 Ω	200.00 Ω	200.00		± 8 digits	± 2 digits
3KΩ	2.0000 KΩ	2.0000	± 8 digits	± 8d	± 2d
30KΩ	20.000 KΩ	20.000	± 8d	± 8d	± 2d
300KΩ	200.00 KΩ	200.00	± 8d	± 10d	± 2d
3MΩ	2.0000 MΩ	2.0000	± 11d	± 31d	± 2d
30MΩ	20.000 MΩ	20.000	± 37d	± 160d	± 2d
300MΩ	200.00 MΩ	200.00	± 301d		± 20d

* Manufacturer's specified uncertainty for the Decade Resistor (D) and the 0.1% 200MΩ resistor. Add uncertainty to the Tolerance to obtain allowable reading if these items are used for the accuracy check.

f. Current Accuracy Check

1) Select DC and A.

2) Select AUTO.

3) Connect Current Source (E) to the instrument input terminals.

4) Set the current source to the currents given in Table 6-5. Verify that each reading is within specified limits.

TABLE 6-5.
DC Current Accuracy Check

RANGE	CURRENT APPLIED	NOMINAL DISPLAY	TOLERANCE (SPECIFIED ACCURACY) IN DIGITS 20° to 30°C	SOURCE ERROR*
300 A	±200.00 A	200.00	±22 digits	±1 digit
3mA	±2.0000mA	2.0000	±22 digits	±1 digit
30mA	±20.000mA	20.000	±22 digits	±1 digit
300mA	±200.00mA	200.00	±22 digits	±4 digit
3 A	±2.0000 A	2.0000	±22 digits**	±4 digit

* Manufacturer's specified uncertainty for Current Sources (E). If these sources are used, add uncertainty to Tolerance to obtain allowable reading.

** Self heating effects of currents greater than 1 ampere can double the percentage of reading error (i.e., prolonged application of >1A can cause tolerance to increase to ±42 digits).

TABLE 6-5.
Recommended Test Equipment For Calibration.

ITEM	DESCRIPTION	SPECIFICATION	MFR	MODEL
A	DC Calibrator	+2.90000V, +29.0000V, +290.000V, +1000.00V, to within 20 ppm	Fluke	343A
B	AC Calibrator	1V @ 1kHz 1V, 100V @ 5kHz	HP	745A
C	Decade Resistor	2KΩ through 10MΩ ±0.01%	ESI	RS725
D	Current Source	1A, 100mA, 10mA ±0.02%	Fluke	383A
E	DMM	1.0000V ± 0.001%	Racal-Dana	5900
F	Test Circuit	Resistor, 2MΩ] Paralleled Capacitor, 1μF]		

6-4. CALIBRATION REQUIREMENTS. In general, calibration should be performed yearly (every 12 months) or whenever the Performance Verification (in this section) indicates that the Model 4004 DMM is out of specifications. It should be noted that if it is desired to make dc voltage measurements to the 6 month or 24 hour accuracy specification, the calibration cycle will have to be shortened accordingly. If any step in the Calibration Procedure cannot be performed properly, refer to Troubleshooting information in this section, or contact your Racal-Dana representative or the factory as described in the Verification Procedure.

NOTE

Calibration should be performed by qualified personnel using accurate and reliable test equipment.

a. Recommended Test Equipment. Recommended test equipment for calibration is listed in Table 6-5. Alternate test may be used. However, the accuracy of the test equipment must be at least five times better than the Model 4004 DMM specifications, or equal to Table 6-1 specifications. For example, to achieve a dc accuracy of 0.015%, the calibration source accuracy should be no worse than 0.003% total. There are several exceptions where other than five times better accuracy is required and these exceptions are noted in the calibration procedure.

b. Environmental Conditions. Calibration should be performed under laboratory conditions having an ambient temperature of 25°C ±1°C, and a relative humidity of less than 80%. If calibration is not done at 25°C, a ±5°C temperature range around that temperature is allowed, but this will result in a shift of the specification temperature range. For example, if calibration is performed at 23°C, the stated 1 year 20°-30°C accuracy specification will then be 1 year 18°-28°C. If the instrument has been subjected to temperatures outside of the calibration temperature range, or to higher than 80% relative humidity, allow one hour minimum for the instrument to stabilize at the specified calibration environmental conditions before beginning the calibration procedure.

6-5. PREPARATION FOR CALIBRATION. Preparation of the Model 4004 DMM for calibration consists of installing the Option 70 calibration cover and allowing a sufficient time for the instrument to warm up after installation of the calibration cover.

a. Installation of the Option 70 Calibration Cover. Calibration should be performed using the Option 70 calibration cover. This cover permits access to the Model 4004 DMM adjustments, while allowing the instrument to reach normal internal operating temperature. Install the cover as follows:

WARNING

Disconnect the line cord before removing the top cover. To discharge voltage on capacitors, depress the LINE pushbutton after disconnecting the line cord.

1) Turn off power and disconnect the line cord.

2) Turn the instrument over so that the bottom cover is facing up, loosen the four screws in the bottom panel. These screws are held captive by rubber O-rings.

3) Hold the top and bottom covers together to prevent their separation and turn the DMM over to normal position.

4) Carefully lift off the top cover and disconnect the connector from the wires going to the rear panel (current fuse).

5) If the Option 51 or 55T Digital Interface is installed, disconnect its connections to the DMM motherboard and remove interface board(s) along with the instrument top cover.

6) If the Option 06 Battery Pack is installed, disconnect its connectors as shown in Figure 2-3 and remove the battery pack from the DMM.

7) Connect P503 from the calibration cover current fuse to J503 from the Model 4004 DMM current board, and position the calibration cover in place on the DMM

b. Warm Up. Connect the line cord and turn power on the instrument by depressing the LINE pushbutton. Allow a one hour warm-up time before beginning the calibration procedure.

6-6. CALIBRATION PROCEDURE. The calibration/adjustment of the Model 4004 DMM consists of performing the procedures outlined as follows:

1. Precalibration.
2. DC voltage calibration.
3. AC voltage calibration.
4. Ohms calibration.
5. DC current calibration.

Precalibration and DC voltage calibration must be done in that order. After completing precalibration and DC voltage calibration, AC voltage, ohms and DC current calibration can be interchanged with each other if desired. Since adjustments within a procedure are interrelated and dependent on prior calibration steps, they must be done only in the order given to ensure proper calibration of the instrument. The circled numbers within the procedures indicate the given order of adjustments for the complete calibration. These numbers are also repeated in Figure 6-1, which shows the adjustment locations by procedural grouping (ie., precalibration, DC voltage calibration and etc.) and serves as an aid to perform the calibration procedure using the calibration cover. Perform the following adjustments to calibrate the Model 4004 DMM and restore its operation to specified limits.

WARNING

Some procedures require the use of high voltage. Take care to prevent contact with live circuits which could cause electrical shock resulting in injury or death. Use an insulated tool when making adjustments.

a. Precalibration.

1) Input Current Adjustment.

a. Set the DMM to MAN; 300 mV DC range.

NOTE

The input short used in the following steps should be no more than 10mΩ ($10^{-2}\Omega$). This can be verified by observing no more than a 1 digit increase when switching from 3KΩ LO range to 300Ω LO range. The short should also have low thermal EMFs, which can be determined by reversing the connections on the dc 300mV range and observing that there is no change in the zero reading.

b. Connect a short between input HI and LO.

c. Record the reading on the DMM.

d. Remove the short and connect the Test circuit (F) across input HI and LO.

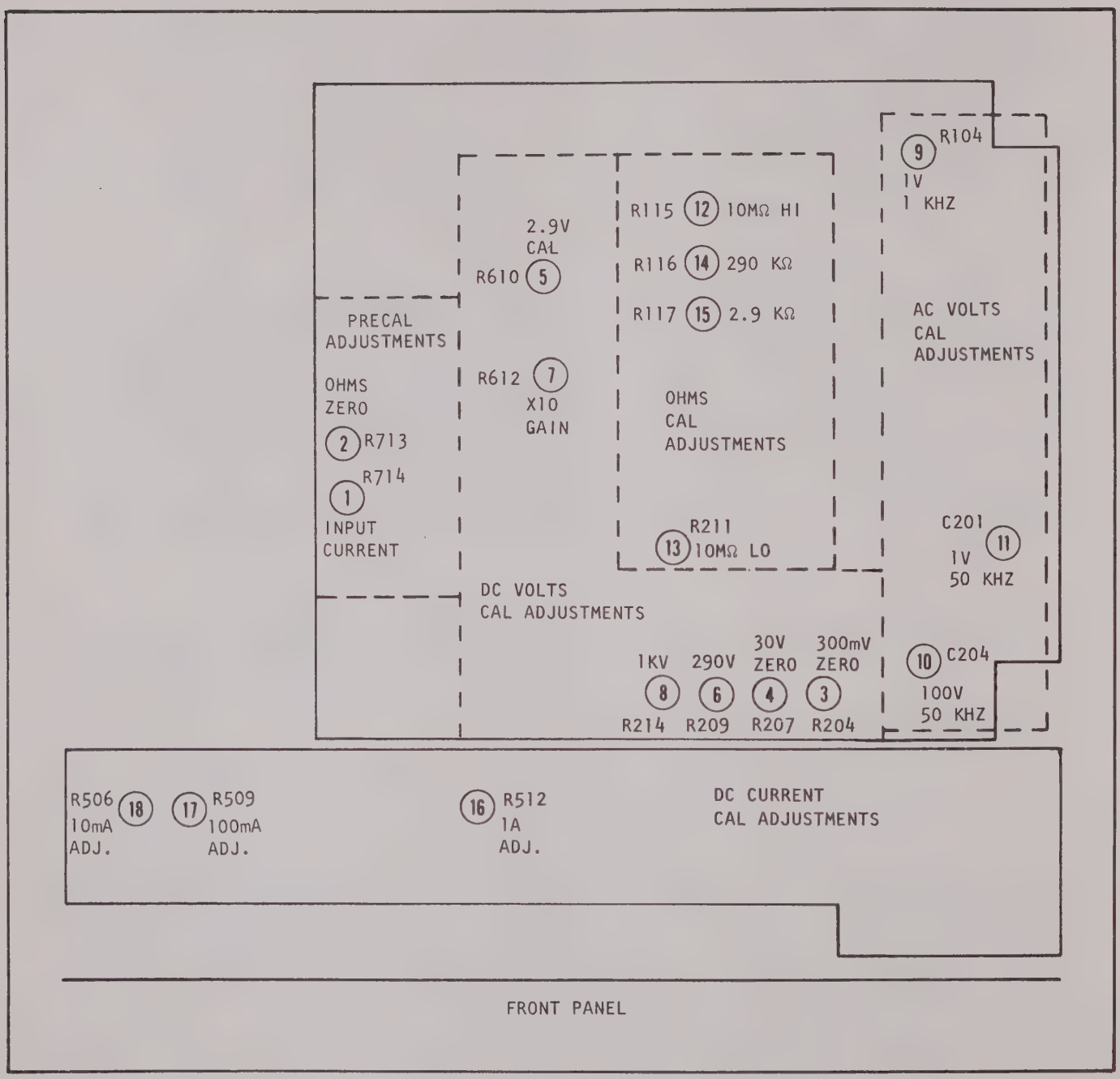


FIGURE 6-1. Location of Calibration Adjustments.

(1) e. Adjust potentiometer R714 (input current) to obtain the same reading as in step c. (Minimize physical movement around input as this will cause a shift in the reading.)

f. Repeat steps b. thru e. to assure equal readings (within ± 1 digit is acceptable.

NOTE

Each digit difference between input shorted and 2MΩ||1μF applied is 5 picoamperes dc.

2) Ohms Zero Adjustment.

a. Set the DMM to 2-WIRE and LO ohms.

b. Select 3KΩ range.

c. Apply short between input HI and LO.

(2) d. Adjust potentiometer R713 (ohms zero) for a zero or zero flashing one reading on the DMM.

e. Select 30KΩ range.

f. Slightly readjust R713 to obtain a zero or zero flashing one reading.

b. DC Voltage Calibration.

1) Zero Adjustments.

a. Select DCV 300mV range.

b. Connect the DC Calibrator (A) to the input terminals.

NOTE

It may be necessary to compensate for dc offset of the DC Calibrator. For example, if the dc offset is -2 μV dc then the DC Calibrator should be adjusted +2 μV to compensate for the offset.

c. Set the DC Calibrator to apply +100μV, ±1μV to DMM input.

(3) d. Adjust potentiometer R204 (300mV zero) for a 00.10 reading on DMM.

e. Select 30Vdc range.

f. Set the DC Calibrator to apply +10mV ±100μV to DMM input.

(4) g. Adjust potentiometer R207 (30V zero) for a 0.010 reading on DMM.

2) Full range Adjustments.

a. Connect the DC Calibrator to the input terminals.

b. Set the instrument to the range given in Table 6-7.

c. Set the DC Calibrator to provide the "Applied Input" given in Table 6-10.

d. Adjust the control given in Table 6-10 to achieve the specified display.

NOTE

Perform the calibration in the exact order given.

TABLE 6-7.
Full Range DC Calibration

RANGE	APPLIED INPUT	CONTROL	DISPLAY REQUIRED
3 V	+2.9V ± 0.003%	(5) 2.9V CAL (R610)	2.9000
300 V	+290V ± 0.003%	(6) 290V ADJ (R209)	290.00
30 V	29V ± 0.003%	(7) X10 GAIN (R612)	29.000
1200 V	1000V ± 0.003%	(8) 1KV ADJ (R214)	1000.0

c. AC Voltage Calibration.

1) Select AC V and MAN ranging.

2) Connect AC Calibrator (B) to the input terminals.

3) 1V at 1kHz Adjustment.

a. Select 3V range.

b. Apply 1 Vac ±0.04% at 1 kHz.

(9) c. Adjust potentiometer R104 (1V, 1kHz) for a 1.0000 ±1 digit reading.

4) 100V at 50kHz Adjustment.

a. Select 300V range.

b. Apply 100V ±0.1% at 50 kHz.

(10) c. Adjust variable capacitor C204 (100V, 50kHz) for a 100.00 ±3 digit reading.

5) 1V at 50kHz Adjustment.

a. Select 3V range

b. Apply 1Vac ±0.1% at 50kHz.

(11) c. Adjust variable capacitor (C201 (1V, 50kHz) for a 1.0000 ±3 digit reading.

d. Ohms Calibration.

1) 10MΩ Adjustment.

a. Select Ω (ohms) and MAN ranging.

b. Select 30MΩ HI range, 2 wire.

c. Connect a 10MΩ ± 0.03% resistor between input upper terminals. (Decade resistor (C) may be used, it has 0.01% accuracy.)

(12) d. Adjust potentiometer R115 (10MΩ HI) for a 10.00 reading on the display.

e. Select 30MΩ LO range; record the change in digits from 10MΩ HI range.

(13) f. Adjust potentiometer R211 (10MΩ LO) for 10MΩ + 1/10 Δ digits.
EXAMPLE: If 10MΩ LO was reading 9.850 (Δ digits = 150), adjust for a reading of 10.015 (1/10 Δ digits = 15 digits).

g. Repeat steps d. through f. until the reading is 10.000 ± 2 digits on HI Ω and 10.000 ± 10 digits on LOΩ.

2) 290KΩ Adjustment.

a. Select 300KΩ HI, 2 wire.

b. Connect the decade resistor (c) between input (upper) terminals. Set decade resistor for 290.000KΩ.

(14) c. Adjust potentiometer R116 (290KΩ) for a reading of 290.00 ±1 digit.

3) 2.9KΩ Adjustment.

a. Select 3KΩ HIΩ, 4 wire.

b. Connect the decade resistor to the instrument using the 2-wire configuration. Set the decade resistor to 2.9000KΩ.

(15) c. Adjust potentiometer R117 (2.9KΩ) for a reading of 2.9000 ±1 digit.

e. DC Current Calibration

1) 1 Ampere Adjustment.

a. Select DCA and MAN ranging.

b. Select 3A range.

c. Connect the current source (D) to the Model 4004 and apply +1 ampere.

(16) d. Adjust potentiometer R512 (1A) for a reading of 1.0000 ±1 digit.

2) 100mA Adjustment.

a. Set the current source for 100.00mA.

b. Select 300mA range.

(17) c. Adjust potentiometer R509 (100mA) for a reading of 100.00 ±1 digit.

3) 10mA Adjustment.

a. Set the current source for 10.00mA.

b. Select 30mA range.

(18) c. Adjust potentiometer R506 (10mA) for a reading of 10.000 ±1 digit.

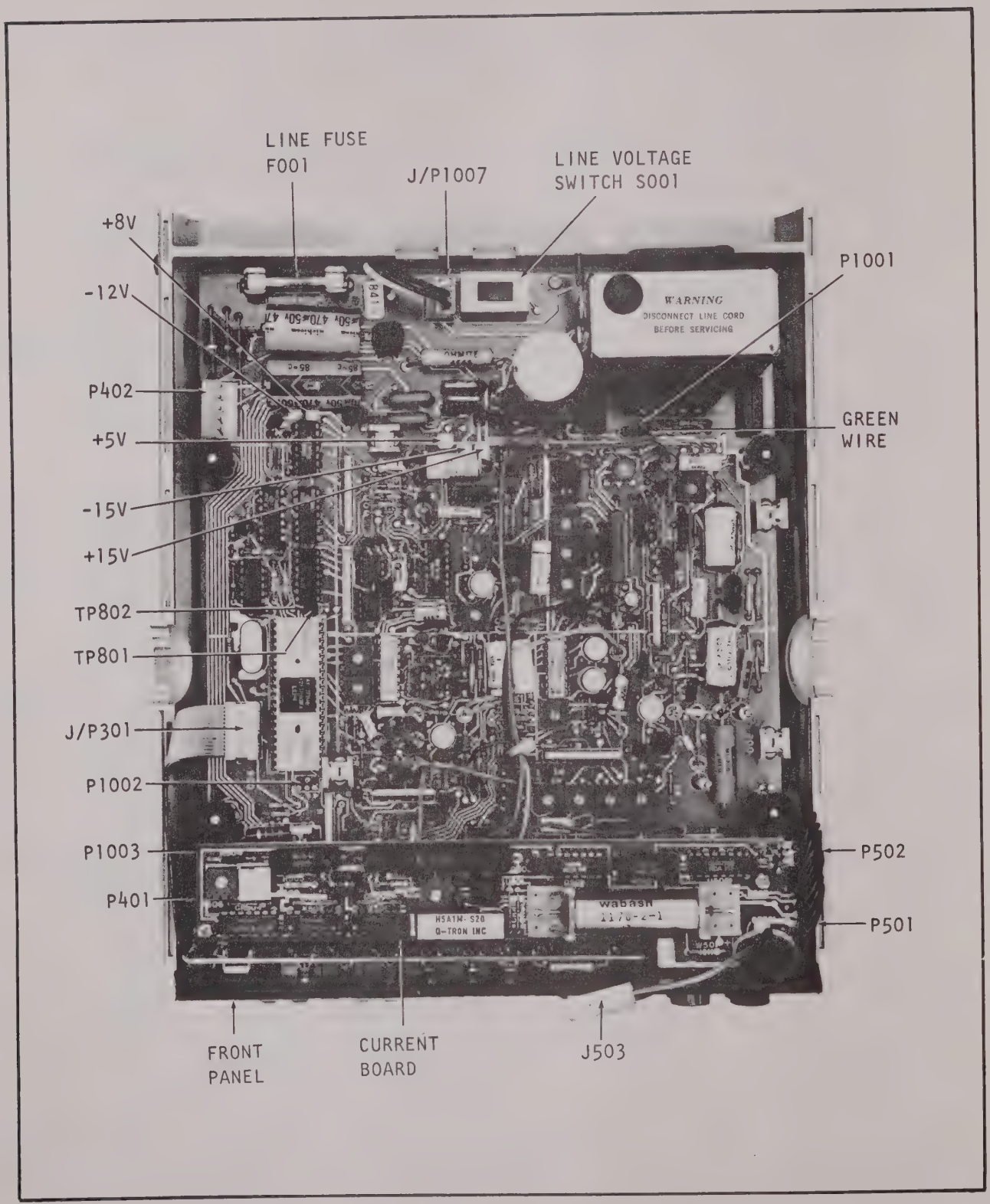


FIGURE 6-2. Location of Connectors and Test Points.

6-7. TROUBLESHOOTING AND REPAIR. The troubleshooting and repair information in this section is intended only for qualified personnel having a basic understanding of analog and digital principles and components used in a precision electronic test instrument. Since most repairs (or replacement of parts) will require that the unit be recalibrated or its performance reverified, a facility having calibration test equipment may also be required. If the required personnel or facilities are not available, or if doubt exists, the Racal-Dana representative in your area should be contacted if repair of the instrument is needed. If it has been determined that you have the means to properly repair and return the Model 4004 DMM to service, the following instructions may prove useful to help you isolate the fault or make the repair. It is strongly recommended that the following instructions be read carefully and that the Theory of Operation and Calibration Procedure both be reviewed, before any attempt is made to repair the DMM

NOTE

For instruments that are still under warranty, (less than 12 months since date of shipment), if the instrument's performance is outside of specifications at any point or if abnormal operation is indicated, contact a Racal-Dana representative or the factory before attempting any troubleshooting or repair, other than fuse replacement.

a. Disassembly. If there is a need to remove the top cover and partially disassemble the Model 4004 DMM for troubleshooting or to replace a part, the following procedure should be followed:

WARNING

Disconnect the line cord before removing the top cover. To discharge voltage on capacitors, depress the LINE pushbutton after disconnecting the line cord.

1) Turn off power and disconnect the line cord.

2) Turn the instrument over so that the bottom cover is facing up, loosen the four screws in the bottom panel. These screws are held captive by rubber O-rings.

3) Holt the top and bottom covers together to prevent their separation and turn the DMM over to normal position.

4) Carefully lift off the top cover and disconnect the connector from the wires going to the rear panel (current fuse).

5) If the Option 51 or 55T Digital Interface is installed, disconnect its connectors to the DMM motherboard and remove interface board(s) along with the instrument top cover. (See Figure 3-9).

6) If the Option 06 Battery Pack is installed, disconnect its connectors as shown in Figure 2-3 and remove the battery pack from the DMM.

NOTE

If the RF shield on the main printed circuit board is removed and replaced, recalibration of the AC voltage circuits may be required. If the position of the shield is disturbed during troubleshooting or repair, perform the AC voltage verification check to determine whether recalibration is needed.

7) The main printed circuit board RF shield is held in place by 4 spring clips. Remove the shield only if absolutely necessary, as its removal and replacement may necessitate recalibrating the AC voltage circuit.

8) To gain access to the display board components (or to remove the display board), first, remove the current board by disconnecting its connector to the main printed circuit board and removing the 2 attaching screws.

b. Special Handling of Static Sensitive Devices. C/MOS devices are designed to function at very low voltage levels for low power consumption. For this reason, a normal static charge build up on your person or clothing can be sufficient to destroy these devices. The following steps list the static sensitive devices in your instrument, or its options, and provide instructions on how to avoid damaging them when they must be removed/replaced.

1) Static sensitive devices:

Racal-Dana Part No.	Reference Designation
IC-103	U1015, U1106
IC-108	U803, U1014, U1107
IC-135	U502
IC-136	U1008 thru U1011
IC-138	U1001 thru U1007, U1012, U1013, U1109
IC-139	U805, U1111
IC-141	U1101 thru U1103, U1105
LSI-4	U901
28090A	U603

2) The above integrated circuits should be handled and transported only in protective containers. Typically they will be received in metal tubes or static protective foam. Keep the devices in their original containers until ready for use.

3) Remove the devices from their protective containers only at a properly grounded work bench or table, and only after grounding yourself by using a wrist strap.

4) Handle the devices only by the body. Do not touch the pins.

5) Any printed circuit board into which a device is to be inserted must also be grounded to the bench or table.

6) Use only anti-static type solder suckers.

7) Use only grounded tip soldering irons.

8) After soldering the device into the board, or properly inserting it into the mating receptacle, the device is adequately protected and normal handling can be resumed.

c. Troubleshooting Hints. Table 6-8 describes the Symptoms and Probable Cause for a variety of possible malfunctions. It is beyond the scope of this Instruction Manual to list all possible symptoms, therefore, it is suggested that you contact the Racal-Dana representative in your area, or the Factory, in the event your instrument needs repair.

TABLE 6-8.
Troubleshooting Hints

SYMPTOM	PROBABLE CAUSE	CORRECTIVE ACTION
a) No display (LINE mode)	1) Line voltage switch (S001) set incorrectly.	Check connection to line power. Check LINE switch setting to conform to line voltage available See Figure 6-2. Check fuse
	2) Fuse F001 is missing or open.	Check fuse. Replace with proper rating.
	3) Line voltage connector J1007 improperly connected to pc board at P1007.	Check connection to pc board as shown in Figure 6-2.
b) No display. (BAT mode)	4) Batteries need recharging. (Check for LO BAT indication.)	Connect instrument to line power. Release LINE.
	2) Battery fuses blown.	Check F401, F402 and F403.
	3) Batteries improperly installed on battery pack.	Check battery pack for proper polarity on all batteries. See Figure 2-3.
	4. Battery cables improperly installed.	Check battery connections at P402 and P401 as in Figure 2-3.
c) No display (All modes)	1) Display cable P301 not properly connected.	Check plug P301 and mating connector J301. Make certain all pins are making proper contact (pins should not be bent). Check for proper orientation of the connector.
	2) LSI module improperly installed.	Check U901 for proper installation. Make certain all pins are making contact (pins should not be bent).
	3) Power supply malfunction.	Check power supply voltages as described in Table 6-9.
d) Display is blank, or some segment on.	1) Clock waveform is missing.	Check pin 4 of LSI U901 for a clock waveform of approx. 334 kHz, swinging between +4V and ØV. If waveform is present, LSI U901 is probably faulty. If waveform is not present, integrated circuits U804, U805 or Crystal Y901 may be faulty.

TABLE 6-8 (CON'T)

e) One display bar missing on all digits.	1) Faulty connection between P301 & J301.	Check plug P301 and mating connector J301. Make certain all pins are making contact.
	2) Cathode driver circuitry faulty. See schematic 27404D	"a" bar: Check R302 pin 14 for signal. When "ON", voltage should be approx. +1.8V. "b" bar: Check R302 Pin 16 "c" bar: Check R302 pin 15 "d" bar: Check R302 pin 9 "e" bar: Check R302 pin 12 "f" bar: Check R302 pin 10 "g" bar: Check R302 pin 13 decimal point: Check R302 pin 11
f) One digit missing.	1) Faulty connection between P301 & J301. 2) Anode drive circuitry faulty. See schematic 27404D.	Check plug P301 and mating connector J301. If units digit missing, check collector of Q305 for signal. When "ON", voltage should be approx. 4.8V. If tems digit missing, check collector of Q304. If hundreds digit missing, check collector Q303. If thousands digit, minus sign and function indicator missing, check collector Q302.
g) 10,000 digit missing. (except if reading is less than 10,000 counts)	Q301	On 10,000 digit, check collector Q301. If no signals are present problem could be transistor or integrated circuit U301.
h) Function indicator off.	Transistor Q306	
i) Faulty reading on Ω function.	1) DMM set for 4 WIRE ohms and Ω SOURCE terminals are not connected.	Set to 2 WIRE.
	2) DMM set for 4 WIRE ohms but leads are reversed.	Connect HI input to the same side of unknown as the + Ω SOURCE Lead.
j) Faulty reading on Current function.	Current fuse F501 is blown.	Replace fuse on rear panel.
k) Faulty reading on all functions.	A/D converter circuitry. See schematic 29145E, Sheet 2.	Check for proper Capture Range of A/D converter as described in Table 6-10.

TABLE 6-9
Line Power Checks

Step	Item/Component	Required Condition	Remarks
1	S001 Line Voltage switch*.	Must be set to 230V or 115V as appropriate.	
2	F001 Line Fuse *	Continuity.	
3	J/P1007*	Properly mated.	
4	P1008 line cord	Plugged into live receptacle.	
5		Turn on power (Line switch).	NOTE: Output from CR002 should be $\geq$ +12.6V. output from CR001 $\geq$ ±26V.
6	+5V pad*	+5volts ±5%.	Output of VR001.
7	+8V pad*	+8volts ±5%	Output of VR004, input to VR001.
8	+15V pad*	+15volts ±5%	Output of VR003.
9	-12V pad*	-12volts ±5%	VR801 & R801
10	-15V pad*	-15volts ±5%	Output of VR002 NOTE: Hot regulator may indicate shorted load.

* On main printed circuit board (See Figure 6-2 for location, and see sheet 3 of Schematic 29145E for circuit details).

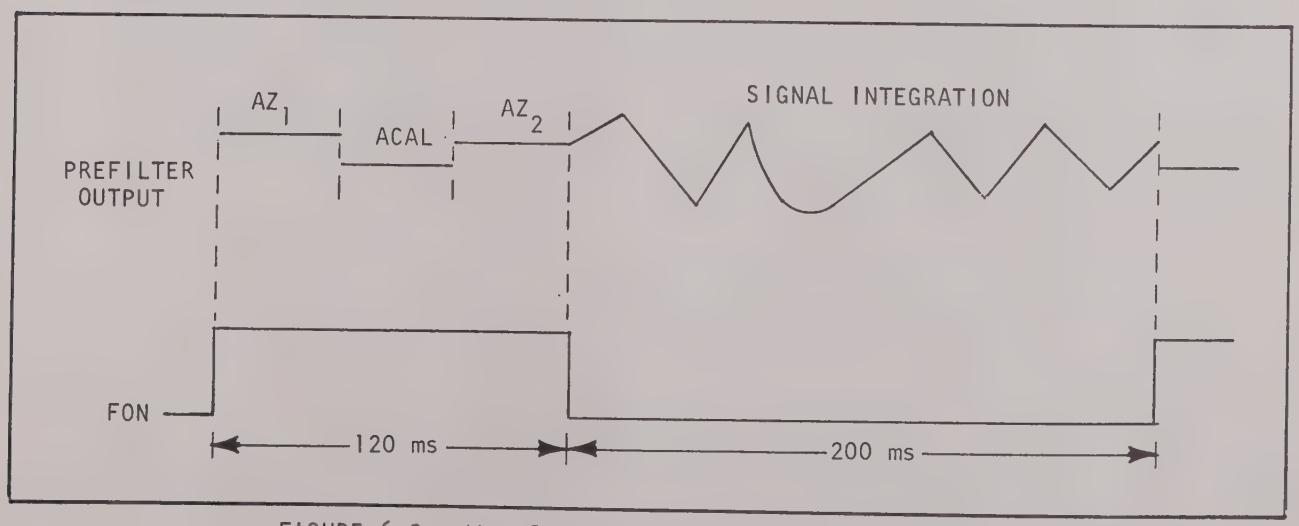


FIGURE 6-3. Waveform for Capture Range Check.

TABLE 6-10
A/D Converter Capture Range Check

Step	Item/Component	Required Condition	Remarks
1	28623A Test Lead (Part of Opt. 70 maintenance Kit)	a) Connect plug such that Black lead to TP801; Red lead to TP802. b) Connect terminal of red lead to oscilloscope EXT. TRIGGER. c) Connect terminal of black lead to oscilloscope VERTICAL INPUT.	See Figure 6-2.
2	28622A Test Lead (P/O Opt. 70)	a) Connect plug (Green wire) to P1001, Pin A. b) Connect terminal of green wire to oscilloscope GND.	See Figure 6-2.
3	Oscilloscope Controls	a) TRIGGER: +, DC coupled. b) VERTICAL: DC, 0.5V/division. c) TIME BASE: 20mS/division.	
4	DMM Settings	a) Turn on power. b) Set to MAN; 300mVDC range. c) Short INPUT HI to LO.	
5	Check waveform, Figure 6-3.	All signals AZ1, ACAL & AZ2 should be +1Vdc ±1Vdc.	If one or more correction signals (AZ1, ACAL, AZ2) are out of capture range, See sheet 2 of Schematic' 29145E for circuit details. Note: There is some interaction between circuits.

6-8. FUSE REPLACEMENT. With the exception of the current fuse, all fuses are located internally To replace the fuse, proceed to step 9.
To replace an internal fuse, proceed as follows:

WARNING

Disconnect the line cord before removing the case cover.

a. Turn off power and disconnect the line cord.

b. Turn the DMM bottom side up and loosen the four screws in the bottom cover. These screws are held captive by rubber O-rings..

c. Hold the top and bottom covers together to prevent their separation and turn the DMM over to normal position.

d. Lift off the top cover.

e. Replacement of Battery Pack fuses. F401, F402 and F403.

1) Leave the Battery pack in place and connected.

2) Remove either F401, F402 or F403 (shown in Figure 2-2) and replace it with a 1A, 250V, 3AG SLO-BLO fuse (Racal-Dana Part No. FU-10).

3) Reinstall top cover.

f. Replacement of Line Fuse F001.

1) Once the top cover is removed, F001 is accessible without removing any other components.

2) Remove F001, shown Figure 6-2, and replace it with a 1/4A, 250V, 3AG SLO-BLO fuse (Racal-Dana Part No. FU-17) for 117V line operation, or a 1/8A, 250V, 3AG SLO-BLO fuse (Racal-Dana Part No. FU-20) for 230V line operation.

3) Reinstall top cover.

g. Current Fuse F501.

1) The current fuse in accessible from the rear panel as shown in Figure 2-1.

2) Replace F501 as follows:

Model 4004: 3A, 250V, 3AG (Racal-Dana Part No. FU-2).

CAUTION

Do not install fuses with higher ratings than specified. Instrument damage may occur.

SECTION 7. REPLACEABLE PARTS.

7-1. GENERAL. This section contains information necessary for ordering replacement parts. Included, to assist you in locating and identifying components, are Cross-Reference Tables, the Replaceable Parts List, Illustrations, Component Layout Diagrams and Schematics. Also included are instructions telling you how to order parts and obtain Factory Service. These items are further described in the following paragraphs.

7-2. ORDERING INFORMATION. Where possible, standard component parts have been used in your instrument. These parts may be ordered directly from your Racal-Dana representative or the factory by using the Racal-Dana part number. It should be noted that in some cases, standard parts are used, but they are either specially selected or matched. These items are identified in the parts list only by Racal-Dana part number and must be ordered from Racal-Dana to ensure that they meet critical circuit requirements. A degradation of the instruments performance will result if these items are replaced with standard components. To place an order or to obtain additional information concerning replacement parts, contact your Racal-Dana representative or the Factory. When ordering, include the following information:

a. Instrument Model Number.

b. Instrument Serial Number.

c. Part Description.

d. Circuit Designation (where applicable).

e. Racal-Dana Part Number.

7-3. FACTORY SERVICE. If the instrument is to be returned to the factory for service, please complete the service form which follows this section and return it with the instrument. Package the instrument for shipment in its original shipping carton, or if it is not available, use a suitable substitute container that is rigid. When a substitute container is used, wrap the instrument in paper or plastic sheeting and surround it with at least four inches of excelsior or other shock-absorbing material. See the inside of the rear cover for the address of the Factory, or other Service Centers.

7-4. REPLACEABLE PARTS LIST. This list is arranged in alphabetical order of the schematic circuit designation of the components and includes the following information:

a. Circuit Designation.

b. Description of Part.

c. Three letter Manufacturer's code (this code is used to access the cross-reference list of manufacturers, Table 7-1).

d. Manufacturer's designation (part number).

e. Racal-Dana Part Number.

In addition to the columnar information above, heading information is contained within the parts list that identifies the applicable schematic and component layout diagrams.

7-5. CROSS-REFERENCE OF MANUFACTURERS. Table 7-1 provides a cross-reference list of manufacturers. The list is arranged in alphabetical order of the three letter manufacturer's codes given in the Replaceable Parts List. The Table includes the manufacturer's name, address and 5-digit federal supply code.

7-6. COVERS AND PANELS. Covers, panels and other miscellaneous items such as the condensed operating instruction label (a metalcal) are not included in the Replaceable Parts List. These items are shown in Figure 7-1 and listed in Table 7-2. Order these parts by using the applicable Racal-Dana part numbers given.

7-7. COMPONENT DESIGNATIONS FOR PC-446. Table 7-3 is a cross-reference listing of the components on the main printed circuit PC-446, which can be used in conjunction with the Component Layout Diagram 28795D (Page 7-32) to physically locate a component when its circuit designation is known. The listing is arranged in the alphabetical order of the circuit designations and includes the item number and zone location of the components, referenced to the Component Layout diagram. Table 7-3 is located on Page 7-31.

7-8. SCHEMATICS.

a. PC-446, Input Signal Conditioning. (29145E, Sheet 1 of 3, Page 7-28). This schematic describes the input switching, ac/dc conversion, filtering, attenuating, relay drivers and ohms source.

b. PC-446, A/D Converter (29145E, Sheet 2 of 3, Page 7-29). This schematic describes the analog-to-digital converter and the reference supply circuitry.

c. PC-446, Power Supply (29145E, Sheet 3 of 3, Page 7-30). This schematic describes the line power supply and the digital section. (See schematic 26758C for the Option 06 Rechargeable Battery Pack.)

d. PC-403, Display (27404D, Page 7-34). This schematic describes the display driver circuitry. Circuit designation series is 300.

e. Current Circuitry (27478D, Page 7-35). This schematic describes the current circuitry for the Model 4004 DMM. Circuit deisgnation series is 500. (PC-406).

f. Option 06 Rechargeable Battery Pack (26758C, Page 7-36),. Circuit designation series is 400.

g. PC-415, Option 51 Digital Interface, Bottom (27902E, Page 7-37). This schematic describes the Option 51 circuitry. Circuit designation series is 1000.

h. PC-416, Option 51 Digital Interface, Upper (28019E, Page 7-38). This schematic describes the Option 51 circuitry. Circuit designation series is 1100.

i. Timing diagrams for Option 51 .

1) 28247E, Page 7-40.

2) 28248E, Page 7-40.

3) 28249D, Page 7-41.

7-9. COMPONENT LAYOUTS. Component layout diagrams are used to illustrate the component parts of the printed circuit boards used in the Model 4004 DMM , the Option 06 Battery Pack and the Option 51 Digital Interface. The component layouts for Option 51 and Option 55 identify the parts by circuit designation which relate directly to the Replaceable Parts List. The other component layouts use item numbers to identify

the parts which relate to a tabular listing contained on the face of the diagrams, or in some cases the listing is on a second sheet. The tabular listing provides a cross-reference to the schematic circuit designation and includes the Racal-Dana part number for convenience.

a. Model 4004 DMM PC-446, Component Layout No. 28795D (Sheet 1 and 2, Page 7-32 and 7-33).

b. Display Board PC-403, Component Layout No. 27879C (Page 7-34).

c. Current Board PC-406 Component Layout No. 27884C (Page 7-35). Page 7-35).

d. Option 06 Battery Pack, Component Layout, Figure 7-2 (Page 7-36).

e. Option 51 PC-415, Component Layout, Figure 7-3 (Page 7-39).

f. Option 51 PC-416, Component Layout, Figure 7-4 (Page 7-39).

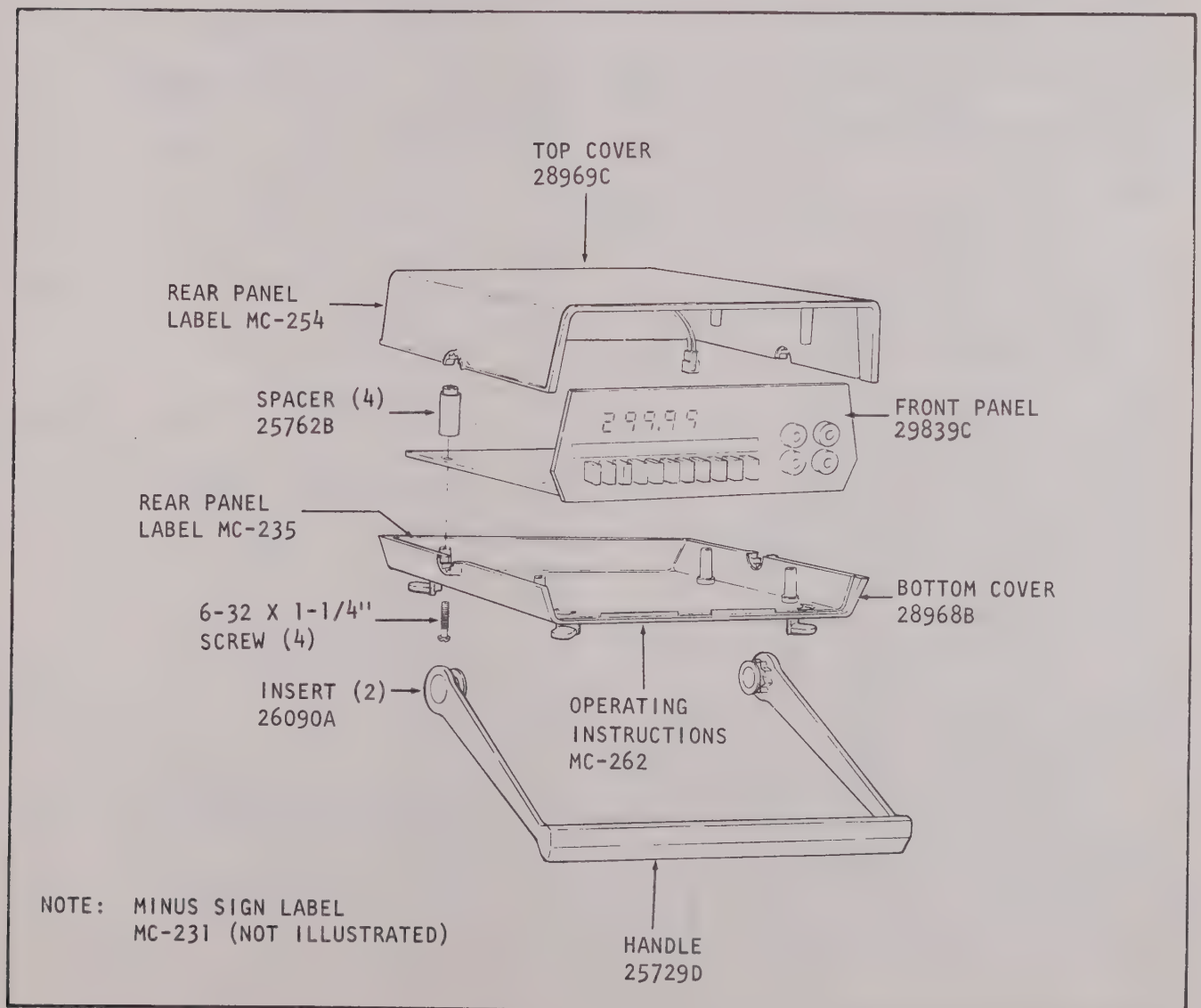


FIGURE 7-1. Top and Bottom Cover Assembly.

TABLE 7-1.
Cross-Reference of Manufacturers

MFR. CODE	NAME AND ADDRESS	FEDERAL SUPPLY CODE	MFR. CODE	NAME AND ADDRESS	FEDERAL SUPPLY CODE
A-B	Allen-Bradley Corp. Milwaukee, WI 53204	01121	H-P	Hewlett Packard Palo Alto, CA 94304	07263
AMP	Amp Inc. Harrisburg, PA 17105	00779	INT	Intersil Inc. Cupertino, CA 95014	32293
BEC	Beckman Inst. Inc. Fullerton, CA 92634	73138	ITT	ITT Semiconductors Lawrence, MA 01841	
BRG	Berg Electronics Inc. New Cumberland, PA 17070	22526	IRC	IRC Division Burlington, IA 52601	07716
BUS	Bussman Mfg. Div. St. Louis, MO. 63017	71400	GLD	Gould Inc. St. Paul, MN 55165	52431
C-I	Components, Inc. Biddeford, ME 04005	06751	L-F	Littlefuse, Inc. Des Plaines, IL 60016	75915
C-W	Continental-Wirt Elec. Warminster, PA 18974	79727	MOL	Molex Downers Grove, IL 60515	27264
CAD	Caddock Riverside, CA 92507	19647	MIC	Miconics Industries Plainsview, NY 11803	21200
CCC	Coto Coil Co. Providence, RI 02905		MOT	Motorola Semi Prod. Inc. Phoenix, AZ 85008	04713
CLB	Centralab Division Milwaukee, WI 53201	71590	MMM	3M Company St. Paul, MN 55101	
DIC	Dickson Elec. Corp. Scottsdale, AZ 85252	12954	NAT	National Semi. Corp. Santa Clara, CA 95051	27014
DLE	Dale Electronics Inc. Columbus, NE 68601	91637	NEL	Northern Engr. Labs Burlington, WI 53105	00815
DTN	Dielettron (Consolidated) New York City, NY 10013		OHM	Ohmite Mfg. Co. Skokie, IL 60076	
ECI	Electro Cube Inc. San Gabriel, CA 91776	14752	P&B	Potter & Brumfield Princeton, IN 47670	
EDI	Electronic Devices, Inc. Yonkers, NY 10710		POM	Pomona Electric Pomona, CA 91766	05276
EFJ	E.F. Johnson Co. Waseca, MN 56093	74970	QTN	Q-Tron Santa Ana, CA 92705	
ERI	Erie Technological Prod. Erie, PA 16512	72982	R-D	Racal-Dana Instruments Irvine, California 92715	21793
F-I	Fairchild Instruments Mountain View, CA 94043	07263	RCA	RCA Corporation Moorestown, NJ 08050	02734

TABLE 7-1 (CON'T)
Cross-Reference of Manufacturers

MFR. CODE	NAME AND ADDRESS	FEDERAL SUPPLY CODE	MFR. CODE	NAME AND ADDRESS	FEDERAL SUPPLY CODE
RIC	Richey Nashville, TN 37207	02734	STD	Standard Condensor Chicago, IL	97419
SIE	Siemens Corporation Iselin, NJ 08830	25088	T-I	Texas Instruments, Inc. Dallas, TX 75231	01295
SIG	Signetics Corp. Sunnyvale, CA 94086	18324	TEP	Tepro Electric Corp. Rochester, NY 14606	02985
SHR	Sheridan Sales, Inc. Cincinnati, Ohio 45222		TRW	TRW Capacitor Div. Ogallala, NE 69153	84411
SPG	Sprague Electric Co. Visalia, CA 93278	14659	WAB	Wabash-Magnetics Wabash, IN 46992	01101

TABLE 7-2.
COVERS, PANELS AND MISCELLANEOUS

DESCRIPTION	Racal-Dana PART NUMBER
Top Cover (less metalcal)	28969C
: : Metalcal for top cover	MC-254
Bottom Cover (less metalcals)	28968B
• • Metalcal, operating instructions	MC-262
• • Metalcal, rear panel	MC-235
Handle (less insert)	25729D
• • Insert (2 req'd)	26090A
Spacer (4 req'd)	25762B
Rubber foot (4 req'd)	FE-10
Front Panel	29839C
"O" Ring (Used to hold display board, 4 req'd)	GA-18
Metalcal, minus sign	MC-231
"O" Ring (Used to hold bottom cover screws captive, 4 req'd)	GA-3

REPLACEABLE PARTS

BATTERIES (BT)

"400" SERIES (Schematic 26758C)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
BT401	Multicell, 19.2V, Nickel-Cadmium	GLD	403041	BA-31
BT402	Multicell, 19.2V, Nickel-Cadmium	GLD	403041	BA-31
BT403	Set of Seven "C" cells, 8.4 Volts	--	--	*
*	Nickel-Cadmium, "C" cell, 1.2 volts (used for BT403; seven required)	GLD	2.0SCB	BA-30

CAPACITORS (C)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
	"000" SERIES (Schematic 29145E) (PC-Board 446)			
C001	2000µF, 25V	RIC	JC-P-2000-25-8P	C-255-2000
C002	.47µF, 50V, CerF.	ERI	813105065147M	C-179-.47
C003	10µF, 20V, ETT.	C-I	TD2-20-106-20	C-179-10
C004	3.3µF, 20V, ETT	C-I	TD1-20-225-20	C-179-3.3
C005	10µF, 20V, ETT, ...	C-I	TD2-20-106-20	C-179-10
C006	.22µF, 250V, MtF.	AMP	C280AE/P220K	C-178-.22
C007	.22µF, 250V, MtF.	AMP	C280AE/P220K	C-178-.22
C008	270µF, 6V, ETT.	C-I	TD5-506277-20	C-194-270
C009	470µF, 50V.	SHR	50ELA470	C-292-470
C010	470µF, 50V.	SHR	50ELA470	C-292-470
C011	10µF, 20V, ETT.	C-I	TD2-20-106-20	C-179-10
C012	2.2µF, 20V, ETT	C-I	TD1-20-225-20	C-179-2.2
	"100" SERIES (Schematic 29145E) (PC-Board 446)			
C101	418pF, 500V, MICA	MIC	DM15RF418pFF03	C-278-418p
C102	.56µF, 50V, MPC	ECI	650B1A564	C-201-.56
C103	8820pF, 1%, Poly.	DTN	8820pF, 63V, 1%	C-299-8820
C104	3.3µF, 20V, ETT	C-I	TD1-20-225-20	C-179-3.3
C105	10µF, 20V, ETT.	C-I	TD2-20-106-20	C-179-10
C106	680µF, 3VDC, ±20%	SPG	199D687X0003FA2	C-297-680
C107	100pF, 1000V, CerD.	CLB	DD-101	C-64-100p

CAPACITORS (C) (CON'T)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
	"200" SERIES (Schematic 29145E) (PC-Board 446)			
C201	.25-1.5pF, 2000V, Teflon Trimmer.	EFJ	273-101	C-184
C202	.05µF, 1000V.	SPG	41C169AB	C-298-.05
C203	3pF, 50VDC	ERI	301-000C0J0309C	C-282-3p
C204	.25-1.5pF, 2000V, Teflon Trimmer.	EFJ	273-101	C-184
C205	10µF, 20V, ETT.	C-I	TD2-20-106-20	C-179-10
C206	.1µF, 16V, CerD	CLB	UK16-104	C-238-1
C207	1500pF, 500V, Poly.	CLB	CPR-1500J	C-138-1500p
C208	1000pF, 500V, Poly.	CLB	CPR-1000J	C-138-1000p
C209	.01µF, 1200V.	STD	PYW-R.01	C-286-.01
C210	.1µF, 50V, MPC.	ECI	625B1A103-J	C-201-.01
	"300" SERIES (Schematic 27404D)			
C301	180µF, 20%, 6V	DIC	D180EC6M1	C-270-180M
C302	0.01µF, 16V, CerD.	CLB	UK16-103	C-238-.01M
	"500" SERIES (Schematic 27478D)			
C501	47 pF, 1000V, CerD	CLB	DD-470	C-64-47P
	"600" Series (Schematic 29145E) (PC-Board 446)			
C601	.1µF, 10%, 200VDC	TRW	1-200-10-X363UW	C-269-.1
C602	33pF, 1000V, CerD	CLB	DD-330	C-64-33p
C603	.22µF, 10%, 200VDC.	TRW	X363UW022	C-269-.22
C604	2200pF, 1000V, CerD	CLB	10SS-D22	C-64-2200p
C605	.22µF, 50V, MPC	ECI	625B1A224J	C-201-.22
C606	.015, 200V, Poly.	ECI	625B1C153	C-221-.015
C607	1µF, 16VDC.	CLB	UK16-104	C-238-.1
C608	6.8pF, 50VDC	ERI	301-000C0H0689C	C-282-6.8p
C609	150pF, 1000V, CerD.	CLB	DD-151	C-64-150p
C610	.015, 200V, Poly.	ECI	625B1C153	C-221-.015
C611	1µF, 16VDC.	CLB	UK16-104	C-238-1
	"700" SERIES (Schematic 29145E) (PC-Board 446)			
C701	.15µF, 10%, 200VDC.	TRW	15-200-10-X363UW	C-269-.15
C702	.15µF, 10%, 200VDC.	TRW	15-200-10-X363UW	C-269-.15
C703	680pF, 1000V, CerD.	CLB	DD-681	C-64-680p
C704	8.2pF, 50V, CerD.	CLB	C40C8P2K	C-282-8.2p
C705	8.2pF, 50V, CerD.	CLB	C40C8R2K	C-282-8.2p
C706	.1µF, 16VDC	CLB	UK16-104	C-238-.1
C707	.1µF, 16VDC	CLB	UK16-104	C-238-.1

CAPACITORS (C) (CON'T)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
	"800" SERIES (Schematic 29145E) (PC-Board 446)			
C801	10µF, 20V, ETT.	C-I	TD2-20-106-20	C-179-10
C802	.1µF, 50V, CerF	ERI	8121050651104M	C-237-.1
	"900" SERIES (Schematic 29145) (PC-Board 446)			
C901	47pF, 1000V, CerD	CLB	DD-470	C-64-47pF
	"1000" SERIES (Schematic 27902E, PC-415)			
C1001	0.01 µF, 500V, CerD	ERI	871-Z5U0-103M	C-22-.01M
C1002	0.01 µF, 16V, CerD.	CLB	UK16-103	C-238-.01M
C1003	0.01 µF, 16V, CerD.	CLB	UK16-103	C-238-.01M
C1004	0.01 µF, 16V, CerD.	CLB	UK16-103	C-238-.01M
C1005	1550 µF, 25V, EAL	RIC	MD16C1550258P	C-272-1550M
C1006	0.01 µF, 500V, CerD	ERI	871-Z5U0-103M	C-22-.01M
C1007	0.01 µF, 16V, CerD.	CLB	UK16-103	C-238-.01M
C1008	1000 pF, 1000V, CerD.	ERI	808-000-Z5R0-102K	C-64-1000P
C1009	0.01 µF, 16V, CerD.	CLB	UK16-103	C-238-.01M
C1010	39 µF, 15V, ETT	C-I	TD401539610	C-228-39M
C1011	0.01 µF, 16V, CerD.	CLB	UK16-103	C-238-.01M
C1012	0.01 µF, 16V, CerD.	CLB	UK16-103	C-238-.01M
C1013	0.01 µF, 16V, CerD.	CLB	UK16-103	C-238-.01M
C1014	0.01 µF, 16V, CerD.	CLB	UK16-103	C-238-.01M
C1015	10 µF, 20V, ETT	ITT	TAP/F010F200	C-179-10M
C1016	0.01 µF, 16V, CerD.	CLB	UK16-103	C-238-.01M
C1017	0.01 µF, 16V, CerD.	CLB	UK16-103	C-238-.01M
C1018	100 µF, 15V, ETT.	C-I	TD501510710	C-228-100M
	"1100" SERIES (Schematic 28019E, PC-416)			
C1101	0.01 µF, 16V, CerD.	CLB	UK16-103	C-238-0.01M
C1102	0.01 µF, 16V, CerD.	CLB	UK16-103	C-238-0.01M
C1103	1.2 µF, 20%, 20V.	C-I	TD1-20-125-20	C-179-1.2M
C1104	0.01 µF, 16V, CerD.	CLB	UK16-103	C-238-0.01M
C1105	0.01 µF, 16V, CerD.	CLB	UK16-103	C-238-0.01M
C1106	220 pF, 1000V, CerD	CLB	DD-221	C-64-220P
C1107	1000 pF, 1000V, CerD.	ERI	808-000-Z5R0-102K	C-64-1000P

DIODES (CR)

"000" SERIES (Schematic 29145)
(PC-Board 446)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
CR001	Bridge Rectifier, 100V, 2A. . . .	EDI	PD10	RF-36
CR002	Bridge Rectifier, 100V, 2A. . . .	EDI	PD10	RF-36

"100" SERIES (Schematic 29145E)
(PC-Board 446)

CR101	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR102	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR103	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR104	Rectifier, 75mA, 75V.	T-I	1N914	RF-28

"200" SERIES (Schematic 29145E)
(PC-Board 446)

CR201	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR202	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR203	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR204	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR205	Rectifier, 1A, 800V	T-I	1N914	RF-28
CR206	Rectifier, 75mA, 75V.	T-I	1N914	RF-28

"300" SERIES (Schematic 29145E)
(PC-Board 446)

CR301	Rectifier, 75mA, 75V.	MOT	1N4006	RF-38

"400" SERIES (Schematic 26758C)

CR401	Rectifier, 75 mA, 75V.	T-I	1N914	RF-28
CR402	Rectifier, 75 mA, 75V.	T-I	1N914	RF-28
CR403	Rectifier, 1 A, 800V	MOT	1N4006	RF-38
CR404	Rectifier, 75 mA, 75V.	T-I	1N914	RF-28
CR405	Rectifier, 75 mA, 75V.	T-I	1N914	RF-28
CR406	Rectifier, 1 A, 800V	MOT	1N4006	RF-38
CR407	Rectifier, 75 mA, 75V.	T-I	1N914	RF-28
CR408	Rectifier, 75 mA, 75V.	T-I	1N914	RF-28
CR409	Rectifier, 1 A, 800V	MOT	1N4006	RF-38
CR410	Rectifier, 75 mA, 75V.	T-I	1N914	RF-28

DIODES (CR)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
	"500" SERIES (Schematic 27478D)			
CR501	Bridge Rectifier, 4 diode, 5A, 50V	EDI	PE05	RF-48
CR502	Rectifier, 75 mA, 75V.	T-I	1N914	RF-28
CR503	Rectifier, 75 mA, 75V.	T-I	1N914	RF-28
CR504	Rectifier, 75 mA, 75V.	T-I	1N914	RF-28
CR505	Rectifier, 75 mA, 75V.	T-I	1N914	RF-28
CR506	Rectifier, 75 mA, 75V.	T-I	1N914	RF-28
CR507	Rectifier, 75 mA, 75V.	T-I	1N914	RF-28
CR508	Rectifier, 75 mA, 75V.	T-I	1N914	RF-28
CR509	Rectifier, 75 mA, 75V.	T-I	1N914	RF-28
	"600" SERIES (Schematic 29145E) (PC-Board 446)			
CR601	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR602	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR603	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR604	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR605	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
	"700" SERIES (Schematic 29145E) (PC-Board 446)			
CR701	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR702	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR703	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR704	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR705	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR706	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR707	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR708	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR709	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR710	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR711	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR712	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
CR713	Rectifier, 75mA, 75V.	T-I	1N914	RF-28
	"800" SERIES (Schematic 29145E) (PC-Board 446)			
CR801	Rectifier, 75mA, 75V.	T-I	1N914	RF-28

DIODES (CR)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
	"1000" SERIES (Schematic 27902E, PC-415)			
CR1001	Rectifier, 75 mA, 75V	T-I	1N914	RF-28
CR1002	Bridge Rectifier, 100V, 2A. . . .	E-D	PD10	RF-36
	"1100" SERIES (Schematic 28019E)			
CR1101	Rectifier, 75 mA, 75V	T-I	1N914	RF-28

DISPLAYS (DS)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
	"300" SERIES (Schematic 27404D)			
DS301	Pilot Light, Red, LED.	H-P	B-031075-2501-1	PL-64
DS302	Pilot Light, Light-Emitting Diode.	H-P	HP5082-4494	PL-63
DS303	Pilot Light, Light-Emitting Diode.	H-P	HP5082-4494	PL-63
DS304	Pilot Light, Light-Emitting Diode.	H-P	HP5082-4494	PL-63
DS305	Pilot Light, Light-Emitting Diode.	H-P	HP5082-4494	PL-63
DS306	Pilot Light, Light-Emitting Diode.	H-P	HP5082-4494	PL-63
DS307	Pilot Light, Light-Emitting Diode.	H-P	HP5082-4494	PL-63
DS308	Pilot Light, Light Emitting Diode.	H-P	HP5082-4494	PL-63
DS309	Pilot Light, Light Emitting Diode.	H-P	HP5082-4494	PL-63
DS310	Pilot Light, Light Emitting Diode.	H-P	HP5082-4494	PL-63
DS311	Digital Display, 7-segment	H-P	5082-7650	DD-13
DS312	Digital Display, 7-segment	H-P	5082-7650	DD-13
DS313	Digital Display, 7-segment	H-P	5082-7650	DD-13
DS314	Digital Display, 7-segment	H-P	5082-7650	DD-13
DS315	Digital Display, 7-segment	H-P	5082-7650	DD-13
	"900" SERIES (Schematic 28656E)			
DS901	Pilot Light, Light Emitting Diode.	H-P	HP5082-4494	PL-63

FUSES (F)
"000" SERIES (Schematic 29145E)
(PC-Board 446)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
F001	Slo-Blo, 1/4A, 3AG (117V)	L-F	313.250	FU-17
	Slo-Blo, 1/8A, 3AG (230V)	BUS	MDL/1/8	FU-20

"400" SERIES (Schematic 26758C)

F401	1A, 3AG, 250V, Slo-Blo	FUS	MDL-1AMP	FU-10
F402	1A, 3AG, 250V, Slo-Blo	FUS	MDL-1AMP	FU-10
F403	1A, 3AG, 250V, Slo-Blo	FUS	MDL-1AMP	FU-10

"500" SERIES (Schematic 27478D)

F501	3A, 250V, 3AG, Quick. . . .	L-F	312003	FU-2

CONNECTORS (J)
"300" SERIES (Schematic 29145E)
(PC-Board 446)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
J301	Socket, 14-Pin DIP.	T-I	C931402	SO-70

"400" SERIES (Schematic 26758C)

J401	5-pins	MOL	2139-5	CS-287-5
J402	5-pins	MOL	2139-5	CS-287-5

"500" SERIES (Schematic 27478D)

J501	5-pin Housing.	BRG	20370	CS-251
J502	8-pin Housing.	BRG	65039C	CS-310
J503	2-pin Housing.	MOL	03-06-1023	CS-326-2
--	Female Contacts (2 req'd for J503)	MOL	02-06-5103	CS-328
--	Female Contacts (12 for J501, J502)	BRG	47439	CS-236

CONNECTORS (J) (CON'T)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
	"1000" SERIES (Schematic 27902E)			
J1001	Housing, 5-pins (mates with CS-236).	BRG	20370	CS-251
J1002	Housing, 6-pins.	BRG	65043-093	CS-335
J1003	Housing, 2-pins, MINI-PV	BRG	65039-035	CS-266
	"1000" SERIES (Schematic 29145E) (PC-Board 446)			
J1001	Housing, 5-Pins (Mates with CS-236) . .	BRG	20370	CS-251
J1002	Housing, 6-Pins	BRG	65043-093	CS-335
J1003	Housing, 2-Pins MINI-PV	BRG	65039-035	CS-266
J1004	NOT USED			
J1005	NOT USED			
J1006	NOT USED			
J1007	Connector, Housing.	MOL	2139-3	CS-287-3
J1008	NOT USED			
J1009	Banana Jack, Red.	POM	1581	BJ-11-2
J1010	Banana Jack, Black.	POM	1581	BJ-22-0
J1011	Banana Jack, Red.	POM	1581	BJ-11-2
J1012	Banana Jack, Black.	POM	1581	BJ-11-0
	"1100" SERIES (Schematic 28019E)			
J1101	Not Used	---	---	---
J1102	Not Used	---	---	---
J1103	Not Used	---	---	---
J1104	Card-edge connector.	MOL	09-52-3102	CS-332-10
J1105	Card-edge connector.	MOL	09-52-3122	CS-332-12

RELAYS (K)
"100" SERIES (Schematic 29145E)
(PC-Board 446)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
K101	5V, Reed Type	COT	UF-40097	RL-56
	"200" SERIES (Schematic 29145E) (PC-Board 446)			
K201	Contact	CCC	SPECIAL	RL-57
K202	Relay	P&B	R10-E3738-1	RL-51

RELAYS (K) (CON'T).

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
	"500" SERIES (Schematic 27478D)			
K501	Relay, Reed, 0.5A, Form A.	WAB	1170-3-1	RL-44
K502	Relay, Reed, 0.5A, Form A.	WAB	1170-3-1	RL-44
K503	Relay, Reed, 0.5A, Form A.	WAB	1170-3-1	RL-44
K504	Relay, Reed, 1.5A, Form A.	QTN	H5A1M-S20	RL-50
K505	Relay, Reed, 3A.	WAB	1170-2-1	RL-49

CONNECTORS (P)
"300" SERIES (Schematic 29145E)
(PC-Board 446)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
P301	Assembly Cable.	---	---	27961A-1
	"400" SERIES (Schematic 29145E) (PC-Board 446)			
P401	Receptacle, 5-Pin	MOL	A-2391-5A	CS-288-5
P402	Receptacle, 2-Pin	MOL	A-2391-5A	CS-288-5
	"500" SERIES (Schematic 28656E)			
P501	Not Used	--	--	--
P502	Not Used	--	--	--
	"1000" SERIES (Schematic 29145E) (PC-Board 446)			
P1001	Receptacle 4-Pin.	BRG	65507-136	CS-339-4
P1002	Contact	R-D	---	24249A
P1003	Receptacle 2-Pin.	BRG	65507-136	CS-339-2
P1004	NOT USED			
P1005	NOT USED			
P1006	NOT USED			
P1007	Receptacle 3-Pin	MOL	---	CS-288-3
P1008	(Part of Line Cord)	R-D	A-2391-3A	CO-9

CONNECTORS (P) (CON'T)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
	"1000" SERIES (Schematic 27902E, PC-415)			
P1001	Not Used	---	---	---
P1002	Not Used	---	---	---
P1003	Not Used	---	---	---
P1004	Connector, 10 pins.	MOL	09-67-1104	CS-331-10
P1005	Connector, 10 pins.	MOL	09-67-1124	CS-331-12
P1006	Card-edge, 40 pins (part of Model 1727)	MMM	3464-0000	CS-294-3
	"1100" SERIES (Schematic 28019E)			
P1101	Card-edge, 26-pin	MMM	3462-0000	CS-294-1

TRANSISTORS (Q)
"100" SERIES (Schematic 29154E)
(PC-Board 446)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
Q101	NPN, Case TO-92	MOT	2N5089	TG-62
Q102	PNP, Silicon, Case TO-92.	MOT	2N5089	TG-61
Q103	PNP, Silicon, Case TO-92.	MOT	2N5087	TG-61
Q104	NPN, Switch	MOT	2N3904	TG-47
Q105	FET, Case TO-18 (*Selected TG-88)	INT	ITS3538	28250A
Q106	Transistor, NON, Case TO-106. . .	R-D	---	28234A
Q107	N-Chan, JFET.	R-D	---	TG-128
Q108	Transistor, NPN, Case TO-106. . .	R-D	---	28234A
Q109	PNP, Silicon, Case TO-92.	MOT	2N5087	TG-61
Q110	N-Chan, JFET.	INT	ITE4392	TG-77
	"200" SERIES (Schematic 29154E) (PC-Board 446)			
Q201	PNP, Silicon.	MOT	2N3906	TG-84
Q202	NPN, Case	F-I	2N3643	TG-123
Q203	PNP, Silicon, TO-92 Case.	MOT	2N3905	TG-53
Q204	N-Chan, JFET.	INT	ITE4392	TG-77
Q205	NPN, Case TO-5.	RCA	2N3439	TG-93
Q206	N-Chan, JFET, Case TO-92.	R-D	----	TG-128

TRANSISTORS (Q)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
	"300" SERIES (Schematic 27404D)			
Q301	PNP, Case TO-106	F-I	2N4355	TG-90
Q302	PNP, Case TO-106	F-I	2N4355	TG-90
Q303	PNP, Case TO-106	F-I	2N4355	TG-90
Q304	PNP, Case TO-106	F-I	2N4355	TG-90
Q305	PNP, Case TO-106	F-I	2N4355	TG-90
Q306	PNP, Case TO-106	F-I	2N4355	TG-90
Q307	PNP, Case R-110	F-I	S17638	TG-33
Q308	PNP, Case R-110	F-I	S17638	TG-33
Q309	PNP, Case R-110	F-I	S17638	TG-33
Q310	PNP, Case R-110	F-I	S17638	TG-33
Q311	PNP, Case R-110	F-I	S17638	TG-33
Q312	PNP, Case R-110	F-I	S17638	TG-33
Q313	PNP, Case R-110	F-I	S17638	TG-33
Q314	PNP, Case R-110	F-I	S17638	TG-33
	"400" SERIES (Schematic 26758C)			
Q401	PNP, Case TO-5	RCA	2N4032	TG-92
Q402	NPN, Case TO-39	MOT	2N3300S	TG-117
Q403	PNP, Case TO-5	RCA	2N4032	TG-92
Q404	NPN, Case TO-106	F-I	2N3565	TG-39
Q405	PNP, Case TO-92	MOT	2N5087	TG-61
	"500" SERIES (Schematic 29145E) (PC-Board 446)			
Q501	Transistor Array - 14-Pin DIP	RCA	CA3086	IC-53
Q502	NPN, Case TO-106	F-I	2N5134	TG-65
	"600" SERIES (Schematic 29145E) (PC-Board 446)			
Q601	N-Chan, JFET	R-D	-----	TG-128
Q602	Transistor, TG-128, (Selected)	R-D	-----	28958A
Q603	N-Chan, JFET	R-D	-----	TG-128
Q604	Transistor, TG-128, (Selected)	R-D	-----	28958A

TRANSISTORS (Q)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
	"700" SERIES (Schematic 29145E) (PC-Board 446)			
Q701	N-Chan, JFET.	R-D	-----	TG-128
Q702	N-Chan, JFET.	R-D	-----	TG-128
Q703	N-Chan, JFET.	R-D	-----	TG-128
Q704	N-Chan, JFET.	R-D	-----	TG-128
Q705	N-Chan, JFET.	R-D	-----	TG-128
Q706	PNP, Silicon, TO-92	MOT	2N3905	TG-53
Q707	N-Chan, JFET.	R-D	-----	TG-128
Q708	N-Chan, JFET.	R-D	-----	TG-128
Q709	Transistor, NPN, CASE TO-106	INT	2N3565	28234A
Q710	Transistor, NPN, CASE TO-106. . .	INT	2N3565	28234A
Q711	N-Chan, JFET.	R-D	-----	TG-128
Q712	N-Chan, JFET.	R-D	-----	TG-128
Q713	Transistor, NPN, Case TO-106. . .	R-D	-----	28234A
Q714	PNP, Silicon, TO-92	MOT	2N3905	TG-53
	"1000" SERIES (Schematic 27902E, PC-415)			
Q1001	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1002	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1003	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1004	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1005	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1006	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1007	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1008	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1009	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1010	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1011	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1012	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1013	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1014	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1015	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1016	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1017	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1018	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1019	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1020	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1021	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1022	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1023	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1024	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1025	NPN, Case TO-106.	F-I	2N5134	TG-65

TRANSISTORS (Q) (CON'T)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
Q1026	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1027	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1028	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1029	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1030	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1031	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1032	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1033	NPN, Case TO-106.	F-I	2N5134	TG-65
Q1034	PNP, Case R-110	F-I	S17638	TG-33
Q1035	PNP, Case R-110	F-I	S17638	TG-33
Q1036	PNP, Case R-110	F-I	S17638	TG-33
Q1037	PNP, Case R-110	F-I	S17638	TG-33
	"1100" SERIES (Schematic 28019E)			
Q1101	NPN, Case TO-106.	F-I	2N5134	TG-65

RESISTORS (R)
"000" SERIES (Schematic 29145E)
(PC-Board 446)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
R001	6.8KΩ, 10%, 1/4W, Comp.	A-B	CB-682-10%	R-76-6.8K
R002	5.1KΩ, 10%, 1/4W, Comp.	A-B	CB	R-76-5.1K
R003	15Ω, 5%, 5W, WW	OHM	4565	R-257-15
R004	NOT USED			
R005	680Ω, 10%, 1/2W, Comp	A-B	EB-681-10%	R-1-680
R006	680Ω, 10%, 1/2W, Comp	A-B	EB-681-10%	R-1-680
R007	100Ω, 10%, 1/2W, Comp	A-B	GB-101-10%	R-2-100
	"100" SERIES (Schematic 29145E) (PC-Board 446)			
R101	SELECTED	R-D		29317D
R102	4.75KΩ, ±0.1%	CAD	R-266	R-266-4.75K
R103	264.2KΩ, ±0.1%.	CAD	R-266	R-266-264.2
R104	50Ω, 0.5W, VAR.	BEC	72PMR-50	RP-97-50
R105	241Ω, ±0.1%, 50V.	DLE	1/8, .1%, C-5	R-241-2191
R106	150KΩ, 10%, 1/4W, Comp.	A-B	CB	R-76-150K
R107	240KΩ, 10%, 1/4W, Comp.	A-B	CB	R-76-240
R108	Thick Film Resistor Network . . .	R-D	-----	TF-72
R109	249Ω, 0.1%, 1/8W, MtF	DLE	1/8, 1%, C-5	R-241-249
R110	10KΩ, 10%, 1/4W, Comp	A-B	CB-103-10%	R-76-10K

RESISTORS (R) (CON'T)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
R111	33.2MΩ, 0.25%, 2W	CAD	MG721	R-242-33.2M
R112	3.295KΩ, 0.1%, 1/8W, MtF.	IRC	MAR-6	R-240-3.295K
R113	10KΩ, 10%, 1/4W, Comp	A-B	CB-103-10%	R-76-10K
R114	335.3KΩ, 0.1%, 1/8W, MtF.	TRW	MAR-6-T10-0.1%	R-241-335.3K
R115	500KΩ, 0.5W, POT.	BEC	72PMR-500K	RP-97-500K
R116	5KΩ, 0.5W, POT.	BEC	72PMR-5K	RP-97-5K
R117	500Ω, 0.5W, POT	BEC	72PMR-50	RP-97-50
	"200" SERIES (Schematic 29145E) (PC-Board 446)			
R201	Selected	R-D	-----	29317D
R202	495KΩ, ±0.1%.	CAD	R-266	R-266-495K
R203	2MΩ, ±0.1%.	CAD	R-266	R-266-2M
R204	200KΩ, 0.5W, POT.	BEC	72PMR-200K	RP-97-200K
R205	120KΩ, 10%, 1/2W, Comp.	A-B	EB-XXX-10%	R-1-120K
R206	Thick Film Resistor Network . . .	R-D	-----	TF-71
R207	200KΩ, 0.5W, POT.	BEC	72PMR-200K	RP-97-200K
R208	49.9KΩ, 1%, 1/8W, MtF	IRC	CEA-T0-49.9K	R-88-49.9K
R209	500Ω, 0.5W, POT	BEC	72PMR-500	RP-97-500
R210	Thick Film Resistor Network . . .	R-D	-----	TF-67
R211	200KΩ, 0.5W, POT.	BEC	72PMR	RP-97-200K
R212	33KΩ, 10%, 1/4W, Comp	A-B	CB	R-76-33
R213	2.7Ω, 10%, 1/4W, Comp	A-B	CB-2R7-10%	R-76-2.7
R214	100Ω, 0.5W, VAR	BEC	72PMR-10	RP-97-100
R215	Thick Film Resistor Network . . .	R-D	-----	TF-75
R216	27KΩ, 10%, 1/2W, Comp	A-B	EB-27K-10%	R-1-27K
R217	150KΩ, 1%, 8W	CAD	MS281	R-247-150K
R218	33KΩ, 10%, 1/4W, Comp	A-B	CB	R-76-33K
	"300" SERIES (Schematic 27404D)			
R301	Thick Film Resistor Network. . . .	R-D	--	TF-42
R302	Thick Film Resistor Network. . . .	R-D	--	TF-43
R303	1 Ω, 1%, 1/2W.	IRC	DCC-1Ω	R-12-1
R304	2.2Ω, 5%, 1/4W	DLE	SBB-2.2Ω	R-248-2.2

RESISTORS(R) (CON'T)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
	"400" SERIES (Schematic 26758C)			
R401	13.7Ω, 1%, 1/8W, MtF	IRC	CEA-T0-13.7Ω	R-88-13.7
R402	12 kΩ, 10%, 1/2W, Comp	A-B	EB-123-10%	R-1-12K
R403	12 kΩ, 10%, 1/2W, Comp	A-B	EB-123-10%	R-1-12K
R404	13.7Ω, 1%, 1/8W, MtF	IRC	CEA-T0-13.7Ω	R-88-13.7
R405	3.3 Ω, 10%, 1/2W, Comp	A-B	EB-3R3-10%	R-1-3.3
R406	1.5 kΩ, 10%, 1/2W, Comp.	A-B	EB-152-10%	R-1-1.5K
R407	71.5 kΩ, 1%, 1/8W, MtF	IRC	CEA-T0-71.5K	R-88-71.5K
R408	100 kΩ, 10%, 1/4W, Comp.	A-B	CB-104-10%	R-76-100K
R409	2.2 kΩ, 10%, 1/4W, Comp.	A-B	CB-222-10%	R-76-2.2K
R410	76.8 kΩ, 1%, 1/8W, MtF	IRC	CEA-T0-76.8K	R-88-76.8K
R411	499 kΩ, 1%, 1/8W, MtF.	IRC	CEA-T0-499K	R-88-499K
R412	100 kΩ, 1%, 1/8W, MtF.	IRC	CEA-T0-100K	R-88-100K
R413	110 kΩ, 1%, 1/8W, MtF.	IRC	CEA-T0-110K	R-88-110K
R414	499 kΩ, 1%, 1/8W, MtF	IRC	CEA-T0-499K	R-88-499K
	"500" SERIES (Schematic 28067D)			
R501	2.2KΩ, 10%, 1/4W	A-B	CB	R-76-2.2K
R502	900 Ω, 0.05%, 1/2W	IRC	MAR6-900Ω	R-236-900
R503	90 Ω, 0.05%, 1/8W.	IRC	MAR6-90Ω	R-236-90
R504	9.1 Ω, 0.5%, 1/2W.	TEP	TS.5S-9.1Ω	R-237-9.1
R505	499 Ω, 1%, 1/8W, MtF	IRC	CEA-T0-499	R-88-499
R506	2 KΩ, 0.5W, Var	BEC	72PMR-10K	RP-97-2K
R507	0.91 Ω, 0.5%, 5W	TEP	TS5-0.91	R-238-.91
R508	40.2 Ω, 1%, 1/8W, MtF.	IRC	CEA-T0-40.2	R-88-40.2
R509	200Ω, 0.5W, Var.	BEC	72PMR-1K	RP-97-200
R510	0.102 Ω, 0.5%, 10W	TEP	TS10-0.102Ω	R-239-.102
R511	2.7 Ω, 10%, 1/4W, Comp	A-B	CB-2R7-10%	R-76-2.7
R512	10 Ω, 0.5W, Var.	BEC	72PMR-10	RP-97-10
R513	Thick Film Resistor Network.	R-D	--	TF-44
R515	30.1KΩ, 1%, 1/8W, MtF.	IRC	CEA-30.1K-1%	R-88-30.1K
R516	30.1KΩ, 1%, 1/8W, MtF.	IRC	CEA-30.1K-1%	R-88-30.1K
R517	30.1KΩ, 1%, 1/8W, MtF.	IRC	CEA-30.1K-1%	R-88-30.1K

RESISTORS (R) (CON'T)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
	"600" SERIES (Schematic 29145E) (PC-Board 446)			
R601	13.44KΩ, 0.5%, 1/8W, MtF.	DLE	MFF-1/8-13.44K	R-246-13.44K
R602	5.76KΩ, 0.5%, 1/8W, MtF	DLE	MFF-1/8-5.76K	R-246-5.76K
R603	133KΩ, 1%, 1/8W, MtF.	IRC	CEA-TO-133K	R-88-133K
R604	133KΩ, 1%, 1/8W, MtF.	IRC	CEA-TO-133K	R-88-133K
R605	Part of 28959B.	R-D	-----	R-246-*
R606	Part of 28959B.	R-D	-----	R-246-*
R607	NOT USED			
R608	15KΩ, 10%, 1/4W, Comp	A-B	CB	R-76-15K
R609	15KΩ, 10%, 1/4W, Comp	A-B	CB	R-76-15K
R610	100Ω, 5%, 500VDC.	BEC	72PMR-100K	RP-114-100
R611	NOT USED			
R612	10Ω, 0.5W, POT.	BEC	72PMR-500	RP-97-10
R613	7.5KΩ, 1%, 1/8W, MtF.	IRC	CEA-TO-7.5K	R-88-7.5K
R614	22KΩ, 10%, 1/4W, Comp	A-B	CB-223-10%	R-76-22K
R615	Thick Film Resistor Network . . .	R-D	-----	TF-70
R616	Thick Film Resistor Network . . .	R-D	-----	TF-69
R617	13.98KΩ, Matched Set.	TEL	-----	R-273-13.98K
R618	15KΩ, Matched Set	TEL	-----	R-273-15K
R619	18.04KΩ, Matched Set.	TEL	-----	R-272-18.04K
R620	2KΩ, Matched Set.	TEL	-----	R-272-2K
R621	900Ω, 0.1%, 1/10 200V	TRW	MAR 5	R-263-900
R622	1.67KΩ, 0.1%, 1/10, 200V.	TRW	MAR 5	R-263-1.67K
	"700" SERIES (Schematic 29145E) (PC-Board 446)			
R701	15KΩ, 10%, 1/4W, Comp	A-B	CB	R-76-15K
R702	22KΩ, 10%, 1/4W, Comp	A-B	CB-223-10%	R-76-22K
R703	22KΩ, 10%, 1/4W, Comp	A-B	CB-223-10%	R-76-22K
R704	150KΩ, 1%, 1/8W, MtF.	IRC	CEA-TO-150K	R-88-150K
R705	10KΩ, 10%, 1/4W, Comp	A-B	CB-103-10%	R-76-10K
R706	7.5Ω, 1%, 1/8W, MtF	IRC	CEA-TO-7.5K	R-88-7.5K
R707	49.9KΩ, 1%, 1/8W, MtF	IRC	CEA-TO-49.9K	R-88-49.9K
R708	210KΩ, 1%, 1/8W, MtF.	IRC	CEA-TO-210K	R-88-210K
R709	10KΩ, 10%, 1/4W, Comp	A-B	CB-103-10%	R-76-10K
R710	47KΩ, 10%, 1/4W, Comp	A-B	CB	R-76-47K
R711	Thick Film Resistor Network . . .	R-D	-----	TF-60
R712	Thick Film Resistor Network . . .	R-D	-----	TF-60
R713	200KΩ, 0.5W, POT.	BEC	72PMR-200K	RP-97-200K
R714	200KΩ, 0.5W, POT.	BEC	72PMR-200K	RP-97-200K
R715	1KΩ, 10%, 1/4W, Comp.	A-B	CB	R-76-1K

RESISTORS (R) (CON'T)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
	"800" SERIES (Schematic 29145E) (PC-Board 446)			
R801	200Ω, 1%, 1/8W, MtF	IRC	CEA-T0-200	R-88-200
R802	22Ω, 10%, 1/4W, Comp.	A-B	CB	R-76-22
R803	270KΩ, 10%, 1/4W, Comp.	A-B	CB	R-76-270K
R804	18KΩ, 10%, 1/4W, Comp	A-B	CB-100-10%	R-76-18K
R805	33KΩ, 10%, 1/4W, Comp	A-B	CB	R-76-33K
R806	12MΩ, 10%, 1/4W, Comp	A-B	CB	R-76-12M
R807	18KΩ, 10%, 1/4W, Comp	A-B	CB-100-10%	R-76-18K
	"900" SERIES (Schematic 29145E) (PC-Board 446)			
R901	Thick Film Resistor	R-D	-----	TF-68
R902	10KΩ, 10%, 1/4W, Comp	A-B	CB-103-10%	R-76-10K
R903	22KΩ, 10%, 1/4W, Comp	A-B	CB-223-10%	R-76-22K
R904	22KΩ, 10%, 1/4W, Comp	A-B	CB-223-10%	R-76-22K
R905	NOT USED			
R906	120KΩ, 5%, 2W, WW	TRW	BWH	R-201-120
	"1000" SERIES (Schematic 27902E)			
R1001	Resistor Network, Thick Film , . .	R-D	-	TF-53
R1002	Resistor Network, Thick Film . . .	R-D	-	TF-53
R1003	Resistor Network, Thick Film . . .	R-D	-	TF-53
R1004	Resistor Network, Thick Film . . .	R-D	-	TF-53
R1005	Resistor Network, Thick Film . . .	R-D	-	TF-53
R1006	1 kΩ, 10%, 1/4W, Comp.	A-B	CB-102-10%	R-76-1K
R1007	32.4 kΩ, 1%, 1/8W, MtF	IRC	CEA-T0-32.4K	R-88-32.4K
R1008	1 MΩ, 10%, 1/4W, Comp.	A-B	CB-105-10%	R-76-1M
R1009	3.9 kΩ, 10%, 1/4W, Comp.	A-B	CB-392-10%	R-76-3.9K
R1010	3.9 kΩ, 10%, 1/4W, Comp.	A-B	CB-392-10%	R-76-3.9K
R1011	154 Ω, 1%, 1/8W, MtF	IRC	CEA-T0-154	R-88-154
R1012	3.9 kΩ, 10%, 1/4W, Comp.	A-B	CB-392-10%	R-76-3.9K
R1013	154 Ω, 1%, 1/8W, Mtf	IRC	CEA-T0-154	R-88-154
R1014	154 Ω, 1%, 1/8W, MtF.	IRC	CEA-T0-154	R-88-154
R1015	154 Ω, 1%, 1/8W, MtF	IRC	CEA-T0-154	R-88-154
R1016	10 Ω, 10%, 1/4W, Comp.	A-B	CB-100-10%	R-76-10
	"1100" SERIES (Schematic 28019E)			
R1101	11 kΩ, 1%, 250V, 1/8W	IRC	CEA-T0-11KΩ	R-88-11K
R1102	Resistor Newwork, Thick Film. . . .	R-D	-	TF-54
R1103	Resistor Network, Thick Film. . . .	R-D	-	TF-54
R1104	Resistor Network, Thick Film. . . .	R-D	-	TF-54
R1105	Resistor Network, Thick Film. . . .	R-D	-	TF-54
R1106	6.5 kΩ, 1%, 1/8W.	IRC	CEA-T0-6.5KΩ	R-88-6.5K
R1107	10 kΩ, 1%, 1/8W	IRC	CEA-T0-10KΩ	R-88-10K

SWITCHES (S)
"000" SERIES (Schematic 29145E)
(PC-Board 446)

S001	Switch, Slide, DPDT	C-W	GF326-0006	SW-397

"700" SERIES (Schematic 29145E)
(PC-Board 446)

S701	Switch, Cutting	R-D	---	28799B

TRANSFORMERS (T)
"000" SERIES (Schematic 29145E)
(PC-Board 446)

T001	Transformer	R-D	-----	TR-163

"1000" SERIES (Schematic 27902E)

T1001	Transformer	R-D	-	TR-164

INTEGRATED CIRCUITS (U)
"100" SERIES (Schematic 29145E)
(PC-Board 446)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
U101	Op. Amp. 8-Pin DIP.	INT	LM308PA	IC-199

"200" SERIES (Schematic 29145E)

U201	Op. Amp. CASE TO-99	F-I	UAF356HC	IC-152
U202	Op. Amp. 8-Pin CASE TO-5.	NAT	LH0042CH	IC-153

"300" SERIES (Schematic 27404D)

U301	8-Bit Parallel-Out Serial Shift Register, 14-Pin DIP.	T-I	SN74LS164	IC-127

"400" SERIES (Schematic 26758C)

U401	Operational Amplifier, 8-pin DIP .	F-I	U9T7741393	IC-42

"500" SERIES (Schematic 27478D)

U501	Operational Amplifier, 8-pin DIP.	INT	LM308PA	IC-99
U502	COS/MOS BCD-TO-DECIMAL decoder, 16-pin DIP.	RCA	CD4028AE	IC-135

INTEGRATED CIRCUITS (U) (CON'T)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
	"600" SERIES (Schematic 29145E) (PC-Board 446)			
U601	Op. Amp. 8-Pin DIP.	F-I	U9T7741393	IC-176
U602	Op. Amp. 8-Pin DIP.	INT	LM308PA	IC-99
U603	Selected IC-153	R-D		28090A
U604	Op. Amp. 8-Pin DIP.	NAT	LM301AN	IC-24
U605	Voltage Comparator.	NAT	LM311N	IC-173
	"700" SERIES (Schematic 29145E) (PC-Board 446)			
U701	JFET, Input Output.	NAT	LM351N	IC-176
U702	Op. Amp. 8-Pin, Case TO-5	NAT	LH0042CH	IC-132
	"800" SERIES (Schematic 29145E) (PC-Board 446)			
U801	Selected IC-53.	R-D	-----	29198A
U802	Flip-Flop, 14-Pin DIP	F-I	9LS74PC	IC-144
U803	Quad 2-Input, NOR, 14-PIN DIP . .	RCA	CD4001AE	IC-108
U804	Flip-Flop, 14-Pin DIP	F-I	9LS74PC	IC-144
U805	COS/MOS Hex Inverter, 14-Pin DIP.	RCA	CD4069BE	IC-139
	"900" SERIES (Schematic 29145E)			
U901	Large Scale Integrated Circuit .	R-D		LSI-4
	"1000" SERIES (Schematic 27902E)			
U1001	Quad 2-Input AND, 14-pin DIP. . . .	RCA	CD4081BE	IC-138
U1002	Quad 2-Input AND, 14-pin DIP. . . .	RCA	CD4081BE	IC-138
U1003	Quad 2-Input AND, 14-pin DIP. . . .	RCA	CD4081BE	IC-138
U1004	Quad 2-Input AND, 14-pin DIP. . . .	RCA	CD4081BE	IC-138
U1005	Quad 2-Input AND, 14-pin DIP. . . .	RCA	CD4081BE	IC-138
U1006	Quad 2-Input AND, 14-pin DIP. . . .	RCA	CD4081BE	IC-138
U1007	Quad 2-Input AND, 14-pin DIP. . . .	RCA	CD4081BE	IC-138
U1008	COS/MOS Dual 4-Stage Static Shift Register.	RCA	CD4015AE	IC-136
U1009	COS/MOS Dual 4-Stage Static Shift Register.	RCA	CD4015AE	IC-136
U1010	COS/MOS Dual 4-Stage Static Shift Register.	RCA	CD4015AE	IC-136
U1011	COS/MOS Dual 4-Stage Static Shift Register.	RCA	CD4015AE	IC-136
U1012	Quad 2-Input AND, 14-pin DIP. . . .	RCA	CD4081BE	IC-138
U1013	Quad 2-Input AND, 14-pin DIP. . . .	RCA	CD4081BE	IC-138
U1014	Quad 2-Input NOR, 14-pin DIP. . . .	RCA	CD4001AE	IC-108
U1015	Dual D-Type Flip-Flop, 14-pin DIP .	RCA	CD4013AE	IC-103

INTEGRATED CIRCUITS (U) (CON'T)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
U1016	COS/MOS Hex Inverter, 14-pin DIP.	RCA	CD4069BE	IC-139
U1017	Timing Logic, 8-pin DIP	SIG	NE555V	IC-71
U1018	Optically-coupled Isolator, 8-pin DIP . . .	H-P	HP5082-4351	IC-142
U1019	Optically-coupled Isolator, 8-pin DIP . . .	H-P	HP5082-4351	IC-142
U1020	Optically-coupled Isolator, 8-pin DIP . . .	H-P	HP5082-4351	IC-142
U1021	Optically-coupled Isolator, 8-pin DIP . . .	H-P	HP5082-4351	IC-142
	"1100" SERIES (Schematic 28019E)			
U1101	Hex Inverters, Open Collector Output.. . .	TEXAS	SN74LS05N	IC-141
U1102	Hex Inverters, Open Collector Output.. . .	TEXAS	SN74LS05N	IC-141
U1103	Hex Inverters, Open Collector Output.. . .	TEXAS	SN74LS05N	IC-141
U1104	Positive-NAND Gates and Inverters/ Totem-pole outputs	TEXAS	SN74LS14N	IC-137
U1105	Hex Inverters, Open Collector Output . . .	TEXAS	SN74LS05N	IC-141
U1106	Dual D-Type Flip-Flop, 14-pin DIP.	RCA	CD4013AE	IC-103
U1107	Quad 2-Input NOR, 14-pin DIP	RCA	CD4001AE	IC-108
U1108	COS/MOS 8-Stage Static Shift Register	RCA	CD4021AE	IC-130
U1109	Quad 2-Input AND, 14-pin DIP	RCA	CD4081BE	IC-138
U1110	COS/MOS Dual 4 Input NAND Gates.	RCA	CD4012AE	IC-140
U1111	Six COS/MOS Hex Inverter	RCA	CD4069BE	IC-139

VOLTAGE REGULATORS (VR)
"000" SERIES (Schematic 29145E)
(PC-Board 446)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Racal-Dana Part No.
VR001	+5V, 3-Term, TO-220	MOT	MC7805CT	IC-93
VR002	+15V, 3-Term, LO-Power	MOT	MC7915CT	IC-174
VR003	15V, CASE TO-220	MOT	MC7815CP	IC-96
VR004	Voltage Regulator +8V, Case TO-92	NAT	LM340LAZ-8.0	IC-164
	"600" SERIES (Schematic 29145E) (PC-Board 446)			
VR601	Zener, 6.3V, (Matched Set)	R-D	-----	28959B
VR602	Zener, Diode, 6.4V	SIE	1N4571	DZ-60
	"700" SERIES (Schematic 29145E) (PC-Board 446)			
VR701	Zener, Diode, 5.1V	MOT	1N751	DZ-59
	"800" SERIES (Schematic 29145E) (PC-Board 446)			
VR801	Zener, Diode, 12V	DIC	1N963B	DZ-54

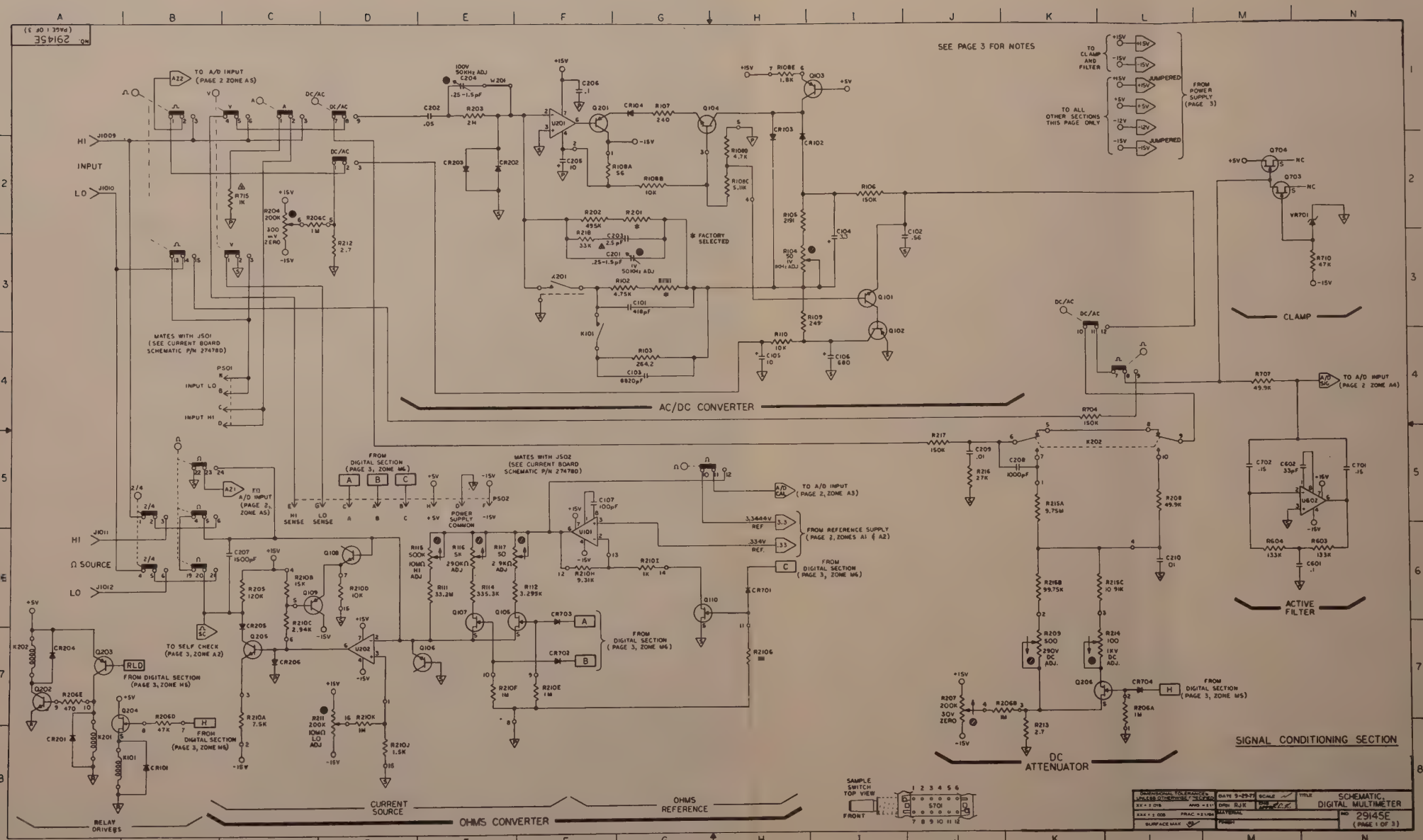
JUMPERS (W)
"100" SERIES (Schematic 29145E)
(PC-Board 446)

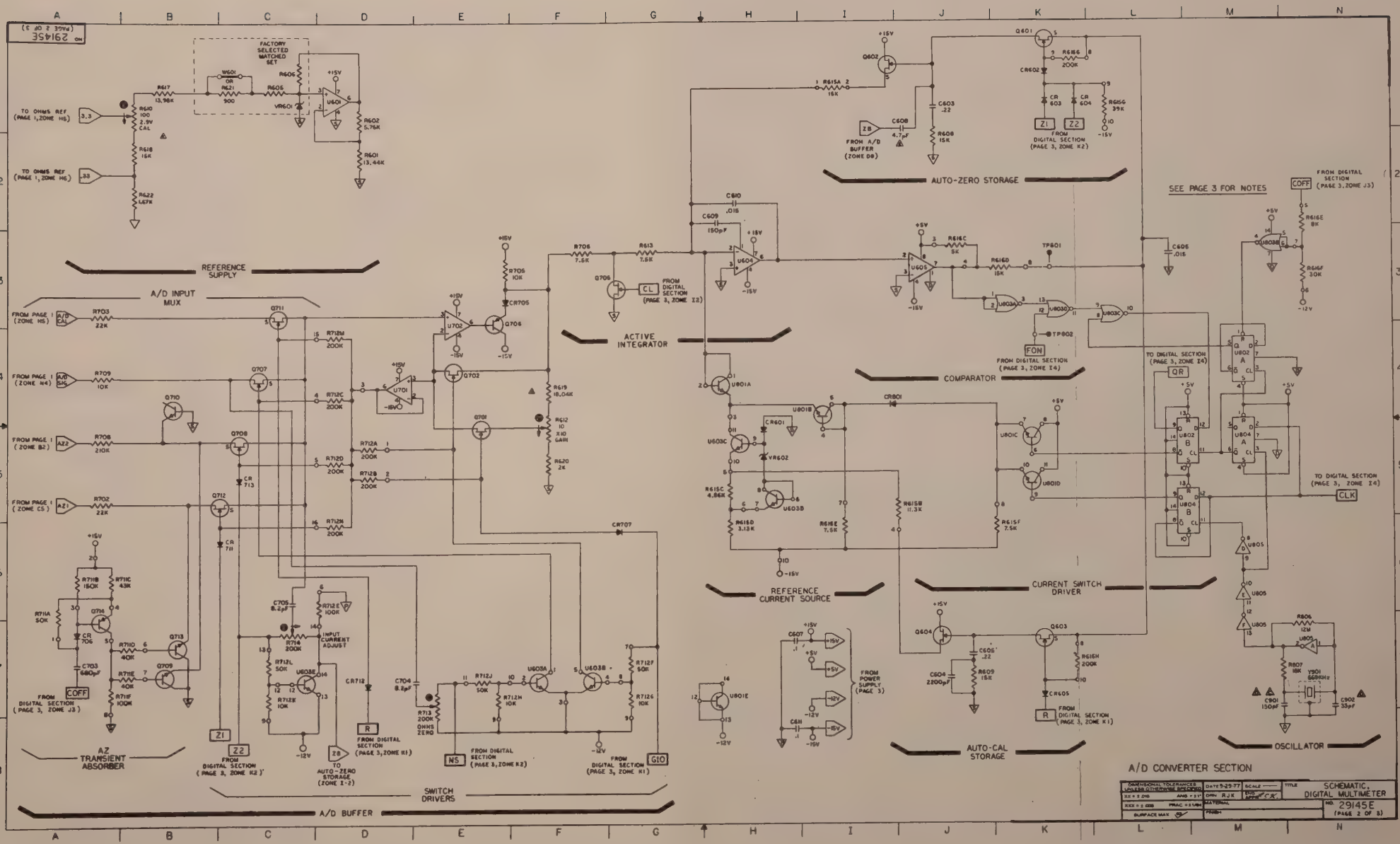
W101	Jumper, Circuit	R-D	-----	J-3
W102	Jumper, Circuit	R-D	-----	J-3
	"200" SERIES (Schematic 29145E) (PC-Board 446)			
W201	Jumper, Circuit	R-D	-----	J-3
	"600" SERIES (Schematic 29145E) (PC-Board 446)			
W601*	Jumper, Circuit (Matched Set)	---	-----	28959B
	"700" SERIES (Schematic 29145E) (PC-Board 446)			
W701	Jumper, Circuit	R-D	-----	J-3

CRYSTAL (Y)
"100" Series (Sch. 29145E)
PC-Board 446)

Y901	Crystal, Quartz, 669 kHz	NEL	NE335PD	CR-9

* Supplied only when necessary to short R611D.


SEE PAGE 3 FOR NOTES
AC/DC CONVERTER
CLAMP
ACTIVE FILTER
DC ATTENUATOR
SIGNAL CONDITIONING SECTION
CURRENT SOURCE
OHMS REFERENCE
OHMS CONVERTER
RELAY DRIVERS
SCHEMATIC, DIGITAL MULTIMETER
29145E
(PAGE 1 OF 3)


A/D CONVERTER SECTION
SCHEMATIC, DIGITAL MULTIMETER
29145E
(PAGE 2 OF 3)
REFERENCE SUPPLY
A/D INPUT MUX
ACTIVE INTEGRATOR
AUTO-ZERO STORAGE
COMPARATOR
REFERENCE CURRENT SOURCE
CURRENT SWITCH DRIVER
AUTO-CAL STORAGE
OSCILLATOR
AZ TRANSIENT ABSORBER
SWITCH DRIVERS
A/D BUFFER
SEE PAGE 3 FOR NOTES
FACTORY SELECTED MATCHED SET
INPUT CURRENT ADJUST
FROM DIGITAL SECTION (PAGE 3, ZONE J3)
FROM DIGITAL SECTION (PAGE 3, ZONE I4)
FROM DIGITAL SECTION (PAGE 3, ZONE I2)
FROM DIGITAL SECTION (PAGE 3, ZONE K2)
FROM DIGITAL SECTION (PAGE 3, ZONE K1)
FROM A/D BUFFER (ZONE D8)
FROM POWER SUPPLY (PAGE 3)
TO AUTO-ZERO STORAGE (ZONE I-2)
TO DIGITAL SECTION (PAGE 3, ZONE I4)
TO OHMS REF (PAGE 1, ZONE H6)
FROM PAGE 1 (ZONE H6)
FROM PAGE 1 (ZONE N4)
FROM PAGE 1 (ZONE B2)
FROM PAGE 1 (ZONE C5)
COFF
FON
CL
QR
CLK
NS
GIO
Z1
Z2
Z8
R

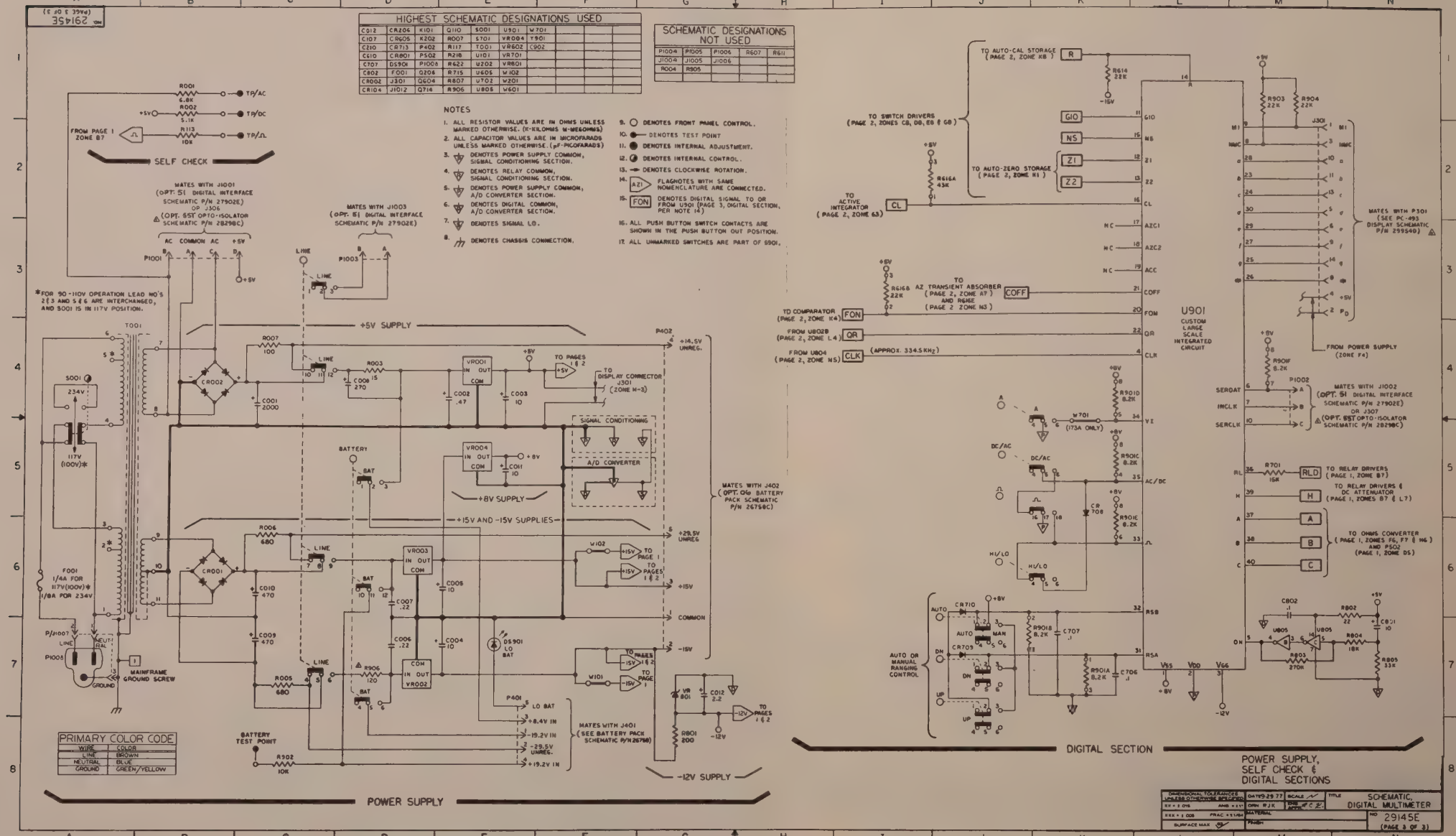
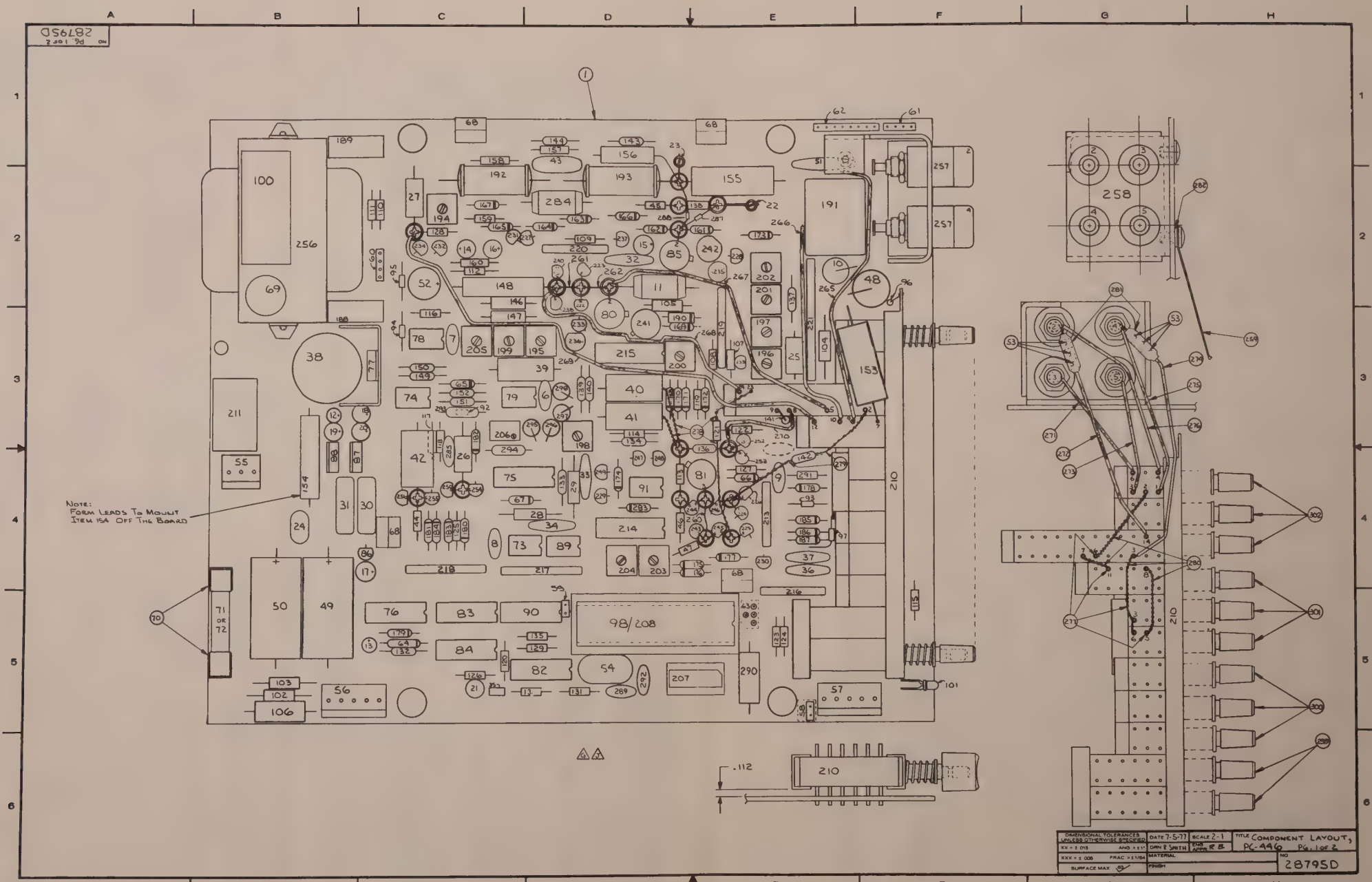

HIGHEST SCHEMATIC DESIGNATIONS USED
SCHEMATIC DESIGNATIONS NOT USED
NOTES
SELF CHECK
+5V SUPPLY
+8V SUPPLY
+15V AND -15V SUPPLIES
-12V SUPPLY
POWER SUPPLY
DIGITAL SECTION
U901
CUSTOM LARGE SCALE INTEGRATED CIRCUIT
PRIMARY COLOR CODE
POWER SUPPLY, SELF CHECK & DIGITAL SECTIONS
SCHEMATIC, DIGITAL MULTIMETER
29145E

TABLE 7-3.
COMPONENT DESIGNATIONS FOR PC-446

Circuit Desig./Item No.		Location Code
C001	38	B3
C002	12	B3
C003	18	C3
C004	19	B3
C005	20	C3
C006	31	B4
C007	30	C4
C008	24	B4
C009	50	B5
C010	49	B5
C011	17	C4
C012	13	C5
C101	43	D1
C102	27	C2
C103	284	D2
C104	14	C2
C105	16	C2
C106	52	C2
C107	7	C3
C201	23	D1
C202	51	E1
C203	45	D2
C204	22	E2
C205	15	D2
C206	32	D2
C207	11	D2
C208	10	E2
C209	48	F2
C210	25	E3
C601	39	D3
C602	6	D3
C603	42	C4
C604	285	C3
C605	26	C4
C606	29	D4
C607	33	D4
C608	44	C4
C609	8	C4
C610	28	D4
C611	34	D4
C701	40	D3
C702	41	D3
C703	9	E4
C704	46	D4
C705	47	D4
C706	37	E4
C707	36	E4
C801	21	C5
C802	35	C5
C901	289	D5
C902	292	D5
CR001	189	B1
CR002	188	B3
CR101	167	C2
CR102	165	C2
CR103	164	D2
CR104	163	D2
CR201	166	D2
CR202	162	D2
CR203	161	E2
CR204	173	E2
CR205	190	D3
CR206	169	D3
CR601	182	C3
CR602	181	C4
CR603	184	C4
CR604	183	C4
CR605	180	C4
CR701	168	D3
CR702	170	D3
CR703	171	D3
CR704	172	E3
CR705	174	D4
CR706	178	E4
CR707	283	D4
CR708	185	E4
CR709	186	E4
CR710	187	E4
CR711	177	E4
CR712	175	E4
CR713	176	E4
CR801	179	C5
DS901	101	F5
F001	71 & 72	B5
J301	207	D5
J1001	-	-
J1002	-	-
J1003	-	-
J1004	-	-
J1005	-	-
J1006	-	-
J1007	-	B4
J1008	-	-
J1009	4	G2
J1010	2	G1
J1011	5	G2
J1012	3	G1
K101	192	C2
K201	193	D2
K202	191	E2
P401	57	E5
P402	56	B5
P501	61	F1
P502	62	E1
P1001	60	C2
P1002	63	E5
P1003	58	E5
P1004	55	B4
Q101	234	C2
Q102	232	C2
Q103	231	C2
Q104	227	D2
Q105	240	D2
Q106	223	D2
Q107	238	D2
Q108	222	D2
Q109	233	D3
Q110	236	D3
Q201	237	D2
Q202	242	E2
Q203	228	E2
Q204	235	E2
Q205	241	D3
Q206	239	E3
Q601	251	C4
Q602	255	C4
Q603	250	C4
Q604	254	C4
Q701	247	D4
Q702	248	D4
Q703	252	E3
Q704	253	E4
Q705	249	D4
Q706	229	D4
Q707	244	E4
Q708	246	E4
Q709	226	E4
Q710	224	E4
Q711	243	E4
Q712	245	E4
Q713	225	E4
Q714	230	E4
R001	111	C2
R002	110	C2
R003	154	B4
R004		
R005	103	B5
R006	102	B5
R007	106	B5
R101	144	D1
R102	157	D1
R103	158	C1
R104	194	C2
R105	159	C2
R106	128	C2
R107	109	D2
R108	220	D2
R109	160	C2
R110	112	C2
R111	148	C2
R112	146	C2
R113	116	C3
R114	147	C3
R115	205	C3
R116	199	C3
R117	195	D3
R201	143	D1
R202	156	D1
R203	155	E2
R204	202	D4
R205	105	D2
R206	219	E3
R207	201	E2
R208	137	E2
R209	197	E3
R210	215	D3
R211	200	D3
R212	108	E3
R213	107	E3
R214	196	E3
R215	221	E3
R216	104	E3
R217	153	F3
R218	138	E2
R601	150	D4
R602	149	C3
R603	139	D3
R604	140	D3
R605	152	C3
R606	151	C3
R607	-	-
R608	117	C3
R609	118	C3
R610	206	C3
R611	-	-
R612	198	D3
R613	133	D4
R614	125	C4
R615	218	C4
R616	217	D4
R617	295	D3
R618	296	D3
R619	297	D3
R620	298	D3
R621	293	C3
R622	294	C4
R701	119	E3
R702	121	E3
R703	122	E3
R704	141	E3
R705	114	D3
R706	134	D3
R707	136	E4
R708	142	E4
R709	113	D4
R710	127	E4
R711	213	E4
R712	214	D4
R713	204	D4
R714	203	D4
R715	291	E4
R801	132	C4
R802	135	D5
R803	129	D5
R804	120	C5
R805	126	C5
R806	130	D5
R807	131	D5
R901	216	E5
R902	115	F5
R903	123	E5
R904	124	E5
R905		
R906	290	E5
S001	211	B3
S701	210	F4
T001	256	B2
U101	78	C3
U201	85	D2
U202	80	D3
U601	74	C3
U602	79	C3
U603	75	C4
U604	73	C4
U605	89	D4
U701	91	D4
U702	81	E4
U801	76	C5
U802	83	C5
U803	90	D5
U804	84	C5
U805	82	D5
U901	98	D5
Y901	54	D5
VR001	77	C3
VR002	88	B4
VR003	87	B4
VR004	86	C4
VR601	65	C3
VR602	67	C4
VR701	66	E4
VR801	64	C5
W101	95	C2
W102	94	C3
W201	287	E2
W601	92	C3
W701	93	E4

TABLE 7-3. (CONTINUED).


28795D
Note: Form Leads To Mount Item 154 Off The Board
.112
DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
XX = ± .015 AND ANG = ± 1°
XXX = ± .005 FRAC = ± 1/64
SURFACE MAX 63
DATE 7-5-77
SCALE 2-1
DRN R SMITH
ENG APPR R B
MATERIAL
FINISH
TITLE COMPONENT LAYOUT, PC-446 PG. 1 OF 2
NO 28795D
FORM 285110

28795D

ITEM	PART NO	SCHEM DESIG	ZONE
1	28794D, STAKING PC446		D1
2	BJ-11-0	J1010	G1
3	"	J1012	G1
4	BJ-11-2	J1009	G2
5	"	J1011	G2
6	C-64-33p	C602	D3
7	C-69-100p	C107	C3
8	C-64-150p	C609	C4
9	C-64-680p	C703	E4
10	C-138-1000p	C208	E2
11	C-138-1500p	C207	D2
12	C-179-.47	C002	B3
13	C-179-2.2	C012	C5
14	C-179-3.3	C104	C2
15	C-179-10	C205	D2
16	"	C105	C2
17	"	C011	C4
18	"	C003	C3
19	"	C004	B3
20	"	C005	C3
21	"	C801	C5
22	C-184	C204	E2
23	"	C201	D1
24	C-194-270	C008	B4
25	C-201-.01	C210	E3
26	C-201-.22	C605	C4
27	C-201-.56	C102	C2
28	C-221-.015	C610	D4
29	"	C606	D4
30	C-178-.22	C007	C4
31	"	C006	B4
32	C-238-.1	C206	D2
33	"	C607	D4
34	"	C611	D4
35	C-237-.1	C802	C5
36	C-238-.1	C707	E4
37	"	C706	E4
38	C-255-2000	C001	B3
39	C-269-.1	C601	D3
40	C-269-.15	C701	D3
41	"	C702	D3
42	C-269-.22	C603	C4
43	C-278-418p	C101	D1
44	C-282-4.7p	C608	C4
45	C-282-2.5p	C203	D2
46	C-282-8.2p	C704	D4
47	"	C705	D4
48	C-286-.01	C209	F2
49	C-292-470	C010	B5
50	"	C009	B5
51	C-298-.05	C202	E1
52	C-297-680	C106	C2
53	CT-4 6/U	~	F3 &G3
54	CR-9	Y901	D5
55	CS-288-3	P1007	B4
56	CS-288-5	P402	B5
57	"	P401	E5
58	CS-339-2	P1003 (TP801 / TP802)	E5
59	"		D5
60	CS-339-4	P1001	C2

ITEM	PART NO.	SCHEM. DESIG.	ZONE
61	CS-339-4	P501	F1
62	CS-339-8	P502	E1
63	24249A 4/U	P1002	E5
64	DZ-54	VR801	C5
65	28959B (DZ-57)	VR601	C3
66	DZ-59	VR701	E4
67	DZ-60	VR602	C4
68	FA-99 4/U	~	(C1, B1) C4, B4
69	FE-10	~	B2
70	FH-12 3/U	~	A5
71	FU-17 OR (117V)	F001	B5
72	FU-20 (234V)		
73	IC-24	U604	C4
74	IC-176	U601	C3
75	28090A	U603	C4
76	29138A	U801	C5
77	28515A (C-91, C-93)	VR001	C3
78	IC-99	U101	C3
79	"	U602	C3
80	IC-132	U202	D3
81	"	U702	E4
82	IC-139	U805	D5
83	IC-144	U802	C5
84	"	U804	C5
85	IC-152	U201	D2
86	IC-164	VR004	C4
87	IC-96	VR003	B4
88	IC-174	VR002	B4
89	IC-173	U605	D4
90	IC-108	U803	D5
91	IC-176	U701	D4
‡ 92	28959B (J3)	W601	C3
93	J-3	W701	E4
94	"	W102	C3
95	"	W101	C2
96	"	~	F2
97	"	~	E4
98	LSI-4	U901	D5
99	LU-90	~	F3
100	MC-221	~	B2
101	PL-63	DS901	F5
102	R-1-680	R006	B5
103	"	R005	B5
104	R-1-2.7K	R216	E3
105	R-1-120K	R205	D2
106	R-2-100	R007	B5
107	R-76-2.7	R213	E3
108	"	R212	E3
109	R-76-240	R107	D2
110	R-76-5.1K	R002	C2
111	R-76-6.8K	R001	C2
112	R-76-10K	R110	C2
113	"	R709	D4
114	"	R705	D3
115	"	R902	F5
116	"	R113	C3
117	R-76-15K	R608	C3
118	"	R609	C3
119	"	R701	E3
120	R-76-18K	R804	C5

ITEM	PART NO.	SCHEM DESIG	ZONE
121	R-76-22K	R702	E3
122	"	R703	E3
123	"	R903	E5
124	"	R904	E5
125	"	R619	C4
126	R-76-33K	R805	C5
127	R-76-47K	R710	E4
128	R-76-150K	R106	C2
129	R-76-270K	R803	D5
130	R-76-12M	R806	D5
131	R-76-18K	R807	D5
132	R-88-200	R801	C4
133	R-88-7.5K	R613	D4
134	"	R706	D3
135	R-76-22	R802	D5
136	R-88-49.9K	R707	E4
137	"	R208	E2
138	R-76-33K	R218	E2
139	R-88-133K	R603	D3
140	"	R604	D3
141	R-88-150K	R704	E3
142	R-88-210K	R708	E4
143	29317D(R4)	R201	D1
144	29317D(R3)	R101	D1
145			
146	R-240-3.295K	R112	C2
147	R-241-335.3K	R114	C3
148	R-242-33.2M	R111	C2
149	R-246-5.76K	R602	C3
150	R-246-13.44K	R601	C3
151	28959B (R-246)	R606	C3
152	"	R605	C3
153	R-247-150K	R217	F3
154	R-257-15	R003	B4
155	R-266-2M	R203	E2
156	R-266-495K	R202	D1
157	R-266-4.75K	R102	D1
158	R-266-264.2	R103	C1
159	R-241-2191	R105	C2
160	R-241-249	R109	C2
161	RF-28	CR203	E2
162	"	CR202	D2
163	"	CR104	D2
164	"	CR103	D2
165	"	CR102	C2
166	"	CR201	D2
167	"	CR101	C2
168	"	CR701	D3
169	"	CR206	D3
170	"	CR702	D3
171	"	CR703	D3
172	"	CR704	E3
173	"	CR204	E2
174	"	CR705	D4
175	"	CR712	E4
176	"	CR713	E4
177	"	CR711	E4
178	"	CR706	E4
179	"	CR801	C5
180	"	CR605	C4

ITEM	PART NO	SCHEM DESIG	ZONE
181	RF-28	CR602	C4
182	"	CR601	C3
183	"	CR604	C4
184	"	CR603	C4
185	"	CR708	E4
186	"	CR709	E4
187	"	CR710	E4
188	RF-36	CR002	B3
189	"	CR001	B1
190	RF-38	CR205	D3
191	RL-51	K202	E2
192	RL-56	K101	C2
193	RL-57	K201	D2
194	RP-97-50	R104	C2
195	"	R117	D3
196	RP-97-100	R214	E3
197	RP-97-500	R209	E3
198	RP-97-10	R612	D3
199	RP-97-5K	R116	C3
200	RP-97-200K	R211	D3
201	"	R207	E2
202	"	R204	E2
203	"	R714	D4
204	"	R713	D4
205	RP-97-500K	R115	C3
206	RP-104-100	R610	C3
207	SO-70	J301	D5
208	SO-84 40	J1201	D5
209	NOT USED		
210	28799B (SW HD)	S701	F4
211	SW-397	S001	B3
212			
213	TF-60	R711	E4
214	TF-66	R712	D4
215	TF-67	R210	D3
216	TF-68	R901	E5
217	TF-69	R616	D4
218	TF-70	R615	C4
219	TF-71	R206	E3
220	TF-72	R108	D2
221	TF-75	R215	E3
222	28234A	Q108	D2
223	"	Q106	D2
224	"	Q710	E4
225	"	Q713	E4
226	"	Q709	E4
227	TG-47	Q104	D2
228	TG-53	Q203	E2
229	"	Q706	D4
230	"	Q714	E4
231	TG-61	Q103	C2
232	"	Q102	C2
233	"	Q109	D3
234	TG-62	Q101	C2
235	TG-77	Q204	E2
236	"	Q110	D3
237	TG-84	Q201	D2
238	TG-128	Q107	D2
239	"	Q206	E3
240	28250A	Q105	D2

ITEM	PART NO	SCHEM DESIG	ZONE
241	TG-93	Q205	D3
242	TG-123	Q202	E2
243	TG-128	Q711	E4
244	"	Q707	E4
245	"	Q712	E4
246	"	Q708	E4
247	"	Q701	D4
248	"	Q702	D4
249	"	Q705	D4
250	"	Q603	C4
251	"	Q601	C4
252	"	Q703	E3
253	"	Q704	E4
254	28958A	Q604	C4
255	"	Q602	C4
256	TR-163	T001	B2
257	27810A 4/U	~	F2
258	27998A	~	G2
259	26533A	~	H3
260	#26 GA BARE COPPER WIRE		E4
261	"	"	D2
262	"	"	D2
263	NOT USED		
264	NOT USED		
265	SC-55	AS REQ'D	E2
266	"	"	E2
267	"	"	E2
268	"	"	E3
269	"	"	E3
270	"	"	E3
271	"	"	G3
272	"	"	G4
273	"	"	G5
274	"	"	H3
275	"	"	H3
276	"	"	H3
277	#22 GA BARE BUSS WIRE		G5
278	TEFLON INS. TUBING	4/U	E3
279	"	2/U	E4
280	"	4/U	H4
281	TX-17-3/16 x 3/16 BLK	2/U	G2
282	WA-71	1/U	G2
283	RF-28	CR707	D4
284	C-299-8820	C103	D2
285	C-64-2200p	C604	C3
286	NOT USED		
287	J-3	W201	E2
288	"	~	E2
289	C-64-150pF	C901	D5
290	R-201-120	R906	E5
291	R-76-1K	R715	E4
292	C-64-33pF	C902	D5
‡ 293	28959B (R-263, R-265)	R621	C3
294	R-263-1.67K	R622	C4
295	R-273 13.98K	R617	D3
296	15K	R618	D3
297	R-272 18.04K	R619	D3
298	2K	R620	D3
299	29465C-3	2/U	H6
300	29465C-4	3/U	H5
301	29465C-6	3/U	H5
302	29465C-7	3/U	H4

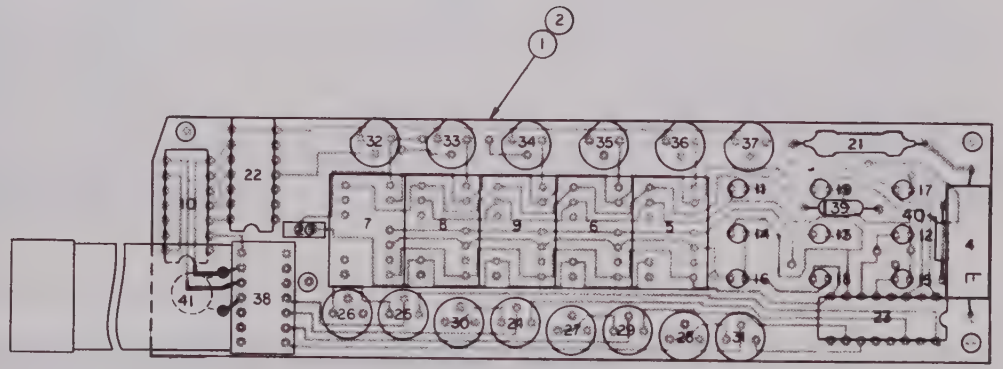
⚠ ‡ EITHER ITEM 92 OR 293 IS INSTALLED DEPENDING UPON 28959B SELECTION

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED	DATE 7-5-77	SCALE ~	TITLE COMPONENT LAYOUT, PC 446 PG. 2 OF 2
XX = ± .015 ANG = ±1°	DRN B. SMITH	ENG APPR. R.B.	
XXX = ± .005 FRAC = ±1/64	MATERIAL		NO 28795D
SURFACE MAX 63	FINISH		

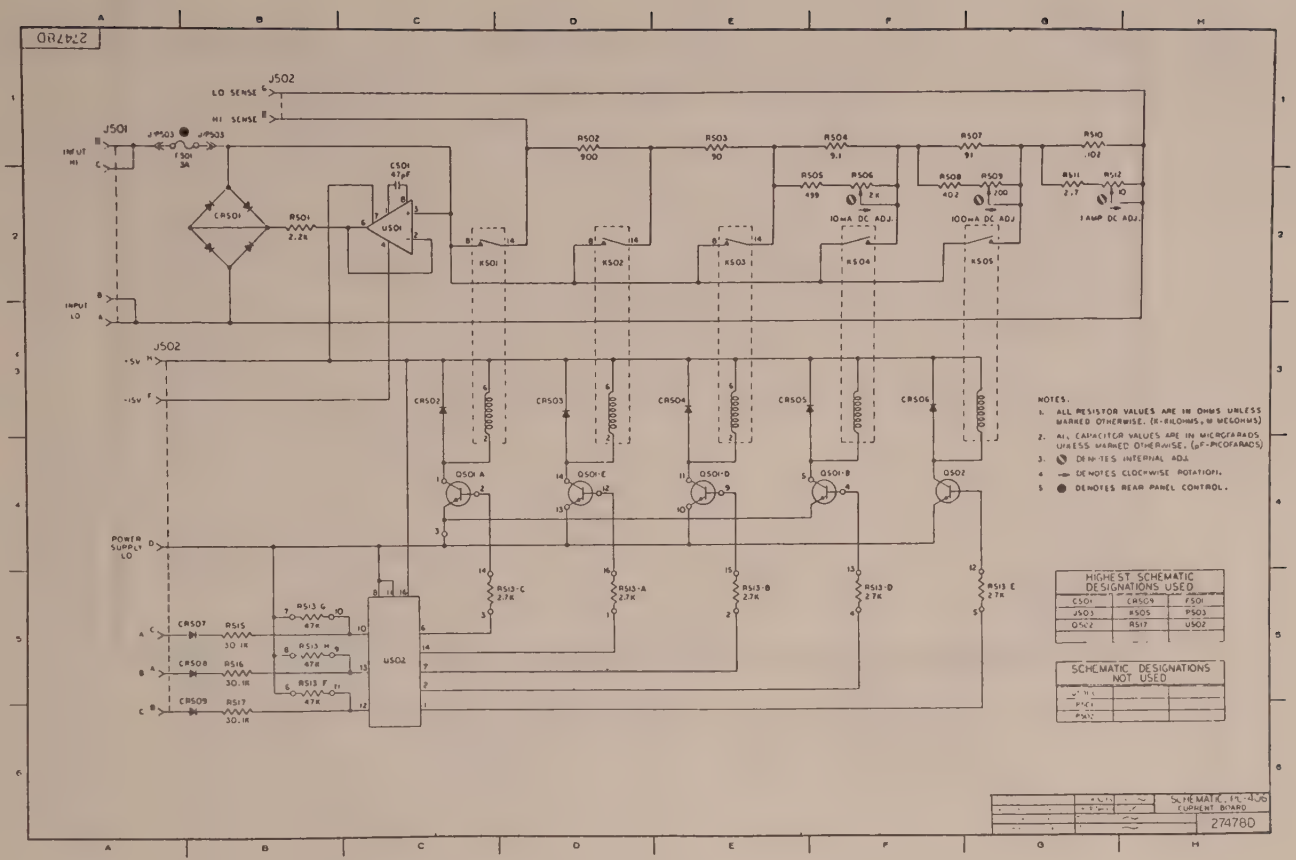
FORM 285118

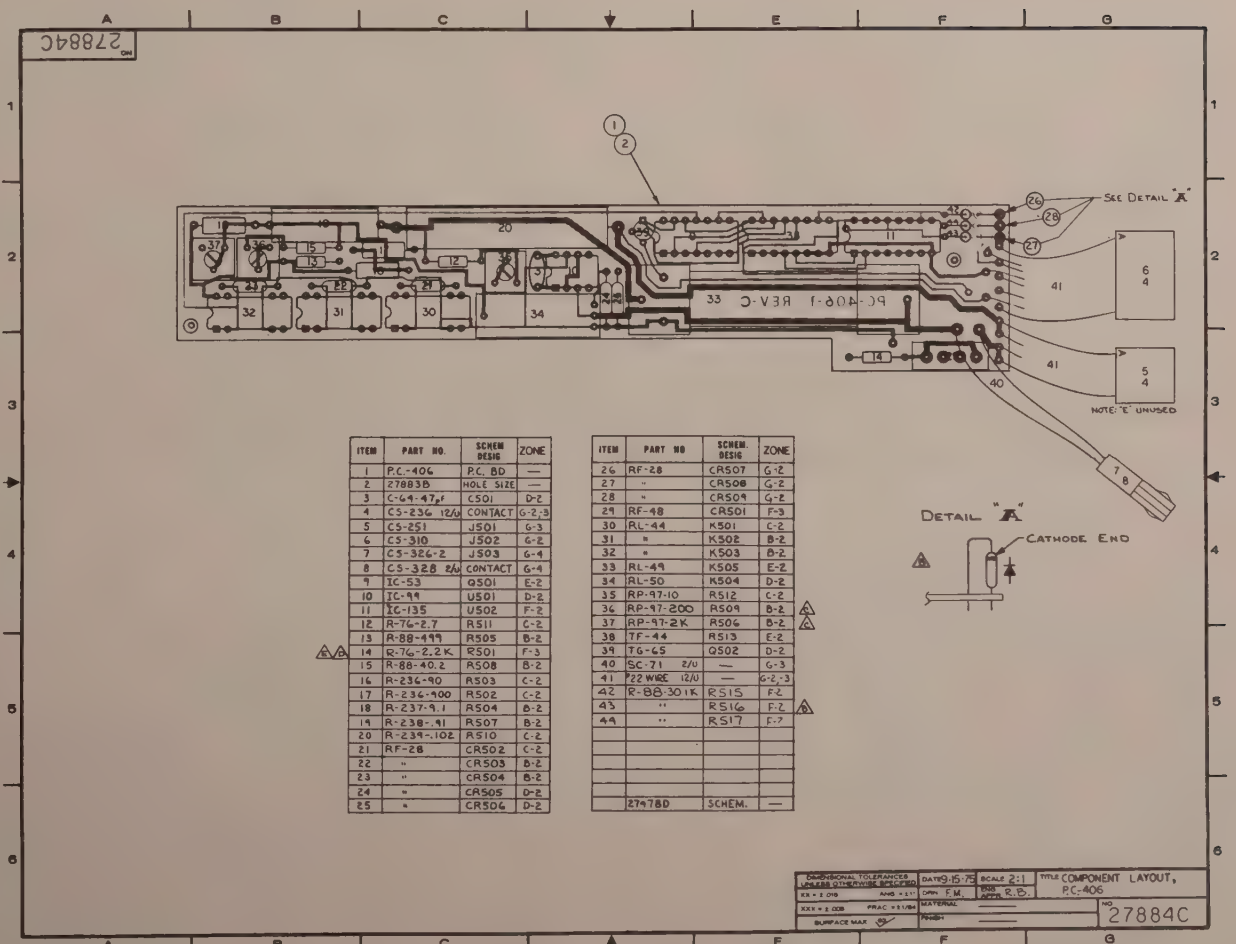
27879C

ITEM	PART NO.	SCHEM. DESIG.	ZONE
1	P.C.-403	P.C. BD.	—
2	278788	HOLE SIZE	—
3	27404D	SCHEM.	—
B 4	C-270-180	C301	G-3
5	DD-13	DS311	E-3
6	"	DS312	E-3
7	"	DS313	D-3
8	"	DS314	D-3
9	"	DS315	E-3
10	IC-127	U301	C-3
11	PL-63	DS302	F-3
12	"	DS303	G-3
13	"	DS304	F-3
14	"	DS305	F-3
15	"	DS306	G-3
16	"	DS307	F-3
17	"	DS308	G-3
18	"	DS309	F-3
19	"	DS310	F-3
20	PL-64	DS301	D-3
21	R-12-1	R303	F-3
22	TF-42	R301	D-3
23	TF-43	R302	F-4
24	TG-33	Q307	E-4
25	"	Q308	D-4
26	"	Q309	D-4
27	"	Q310	E-4
28	"	Q311	F-4
29	"	Q312	E-4
30	"	Q313	E-4
31	"	Q314	F-4
32	TG-90	Q301	D-3
33	"	Q302	E-3
34	"	Q303	E-3
35	"	Q304	E-3
36	"	Q305	F-3
37	"	Q306	F-3
38	27961A-1	ASS'Y, CABLE	D-3
B 39	RF-38	CR301	F-3
E C B 40	R-76-2.2	R304	G-3
A 41	C-238-.01	C302	C-3



DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED	DATE 9-2-75	SCALE 2:1	TITLE COMPONENT LAYOUT, P.C.-403
XX = ± .015 ANG = ±1°	DRN F.M.	ENG APPR R.B.	
XXX = ± .005 FRAC = ±1/64	MATERIAL		NO 27879C
SURFACE MAX 63	FINISH		





ITEM	PART NO.	SCHEM DESIG	ZONE
1	P.C.-406	P.C. BD	—
2	27883B	HOLE SIZE	—
3	C-69-47pF	C501	D-2
4	CS-236 12/U	CONTACT	G-2,3
5	CS-251	J501	G-3
6	CS-310	J502	G-2
7	CS-326-2	J503	G-4
8	CS-328 2/U	CONTACT	G-4
9	IC-53	Q501	E-2
10	IC-99	U501	D-2
11	IC-135	U502	F-2
12	R-76-2.7	R511	C-2
13	R-88-499	R505	B-2
14	R-76-2.2K	R501	F-3
15	R-88-40.2	R508	B-2
16	R-236-90	R503	C-2
17	R-236-900	R502	C-2
18	R-237-9.1	R504	B-2
19	R-238-.91	R507	B-2
20	R-239-.102	R510	C-2
21	RF-28	CR502	C-2
22	"	CR503	B-2
23	"	CR504	B-2
24	"	CR505	D-2
25	"	CR506	D-2

ITEM	PART NO	SCHEM. DESIG	ZONE
26	RF-28	CR507	G-2
27	"	CR508	G-2
28	"	CR509	G-2
29	RF-48	CR501	F-3
30	RL-44	K501	C-2
31	"	K502	B-2
32	"	K503	B-2
33	RL-49	K505	E-2
34	RL-50	K504	D-2
35	RP-97-10	RS12	C-2
36	RP-97-200	RS09	B-2
37	RP-97-2K	RS06	B-2
38	TF-44	RS13	E-2
39	TG-65	QS02	D-2
40	SC-71 2/U	—	G-3
41	22 WIRE 12/U	—	G-2,3
42	R-88-301K	RS15	F-2
43	"	RS16	F-2
44	"	RS17	F-2
	27478D	SCHEM.	—

26758C

J401
+8.4V OUT
+14.5V UNREG.
J402
+19.2V OUT
+29.5V UNREG.
COMMON
-29.5V UNREG.
-19.2V OUT
-15V
TO LO BAT LED
+15V

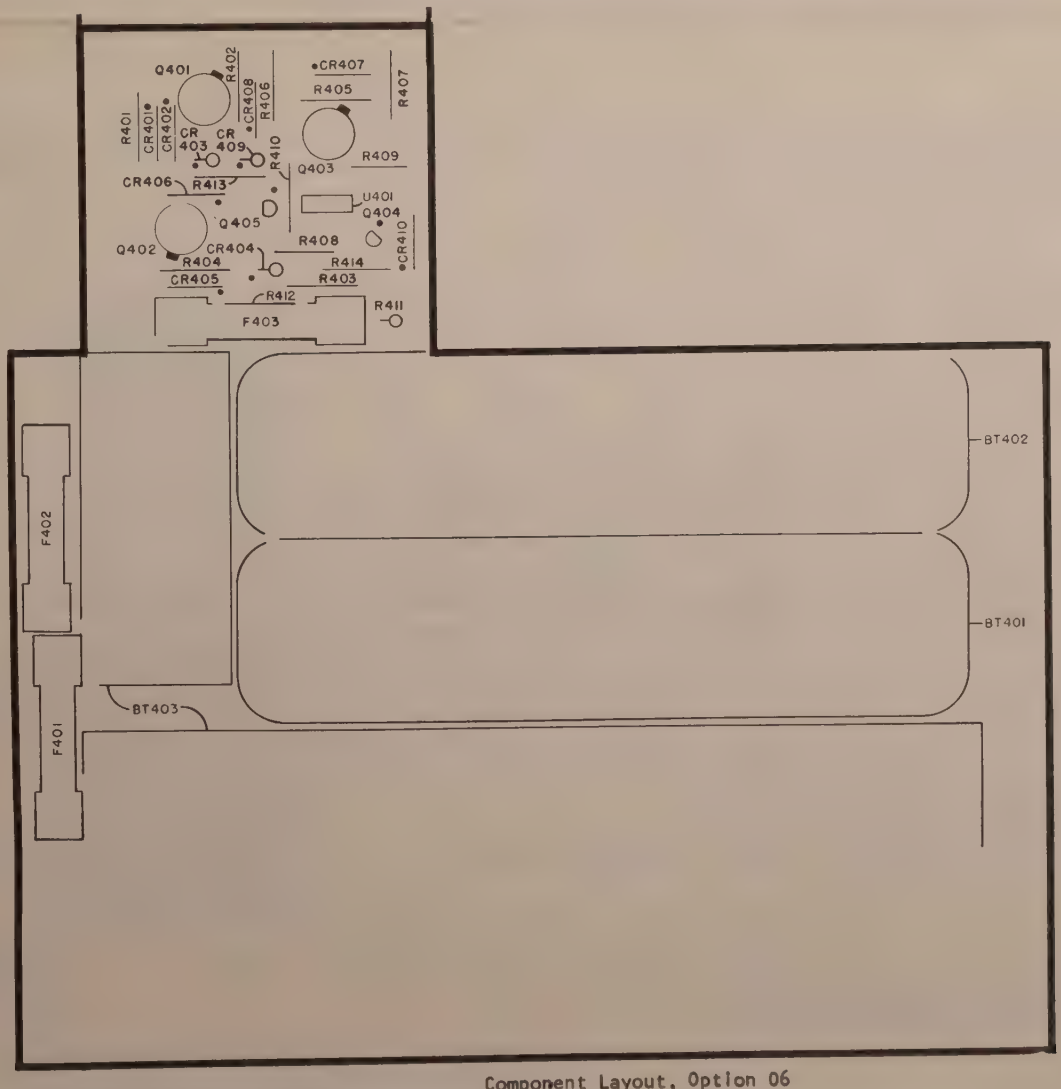
R413 110K
R405 3.3
Q403
CR409
CR407
CR408
F403 1A
BT403 8.4V 2 AH
R408 100K
R401 13.7
Q401
CR403
CR401
CR402
F401 1A
BT401 19.2V .45AH
R406 1.5K
R402 12K
R414 499K
R411 499K
Q404
R403 12K
BT402 19.2V .45AH
R407 71.5K
R412 100K
Q405
CR404
CR405
F402 1A
U401
R404 13.7
Q402
CR406
R409 2.2K
R410 76.8K
CR410

NOTES:
1. ALL RESISTOR VALUES ARE IN OHMS UNLESS MARKED OTHERWISE. (K-KILOHMS)
2. ▽ DENOTES POWER SUPPLY COMMON.

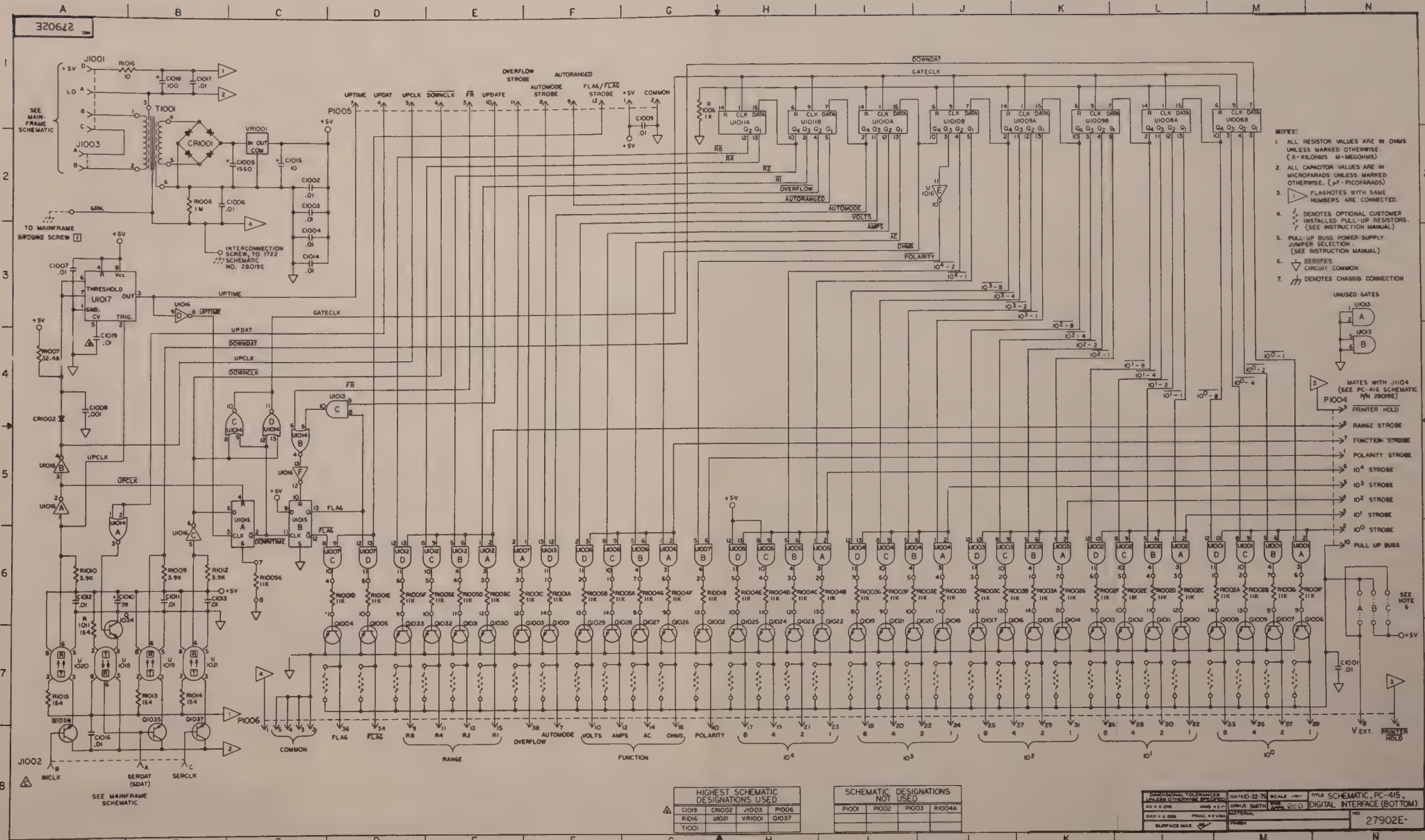
HIGHEST SCHEMATIC DESIGNATIONS USED		
BT403	CR410	F403
J402	Q405	R414
U410		

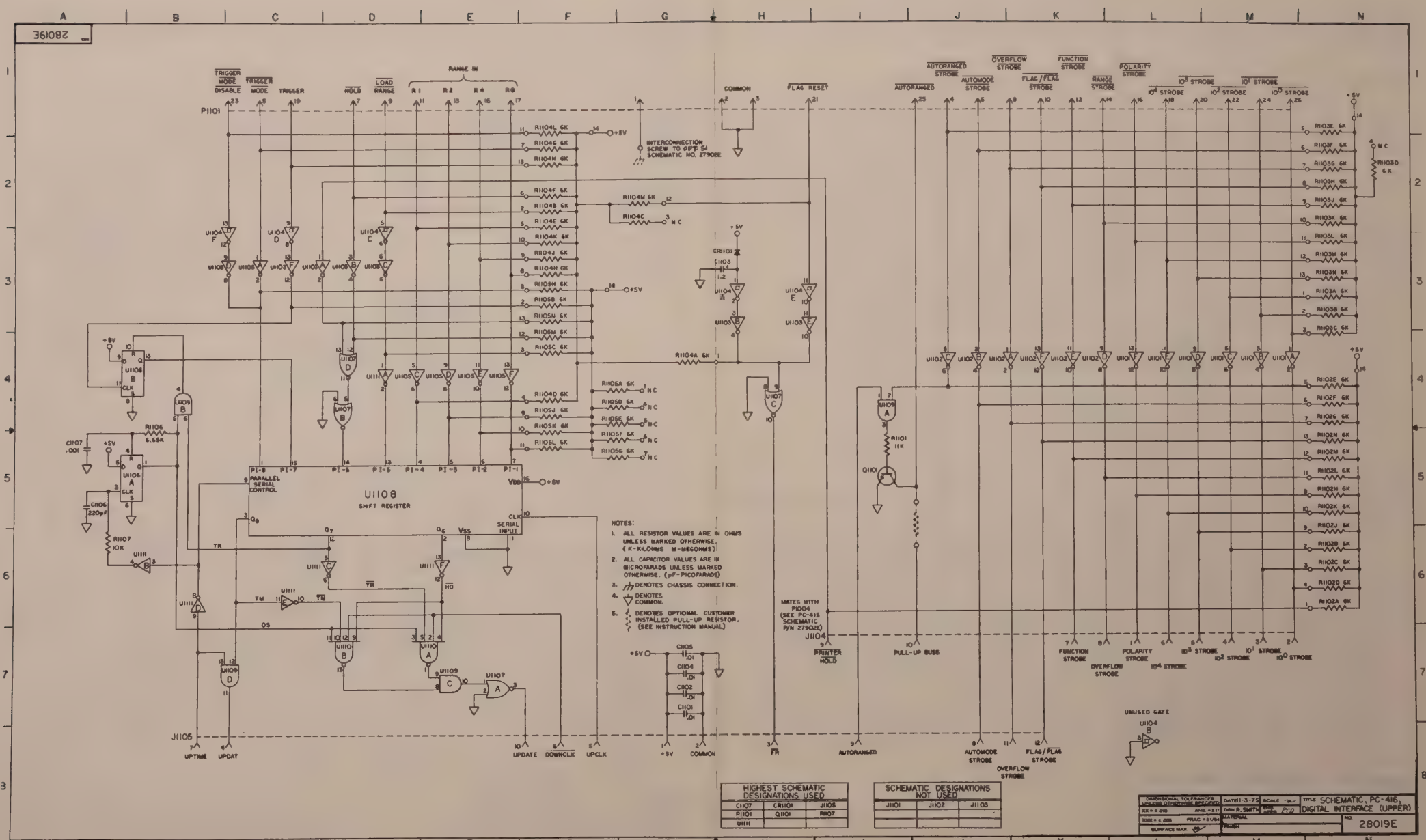
SCHEMATIC DESIGNATIONS NOT USED		

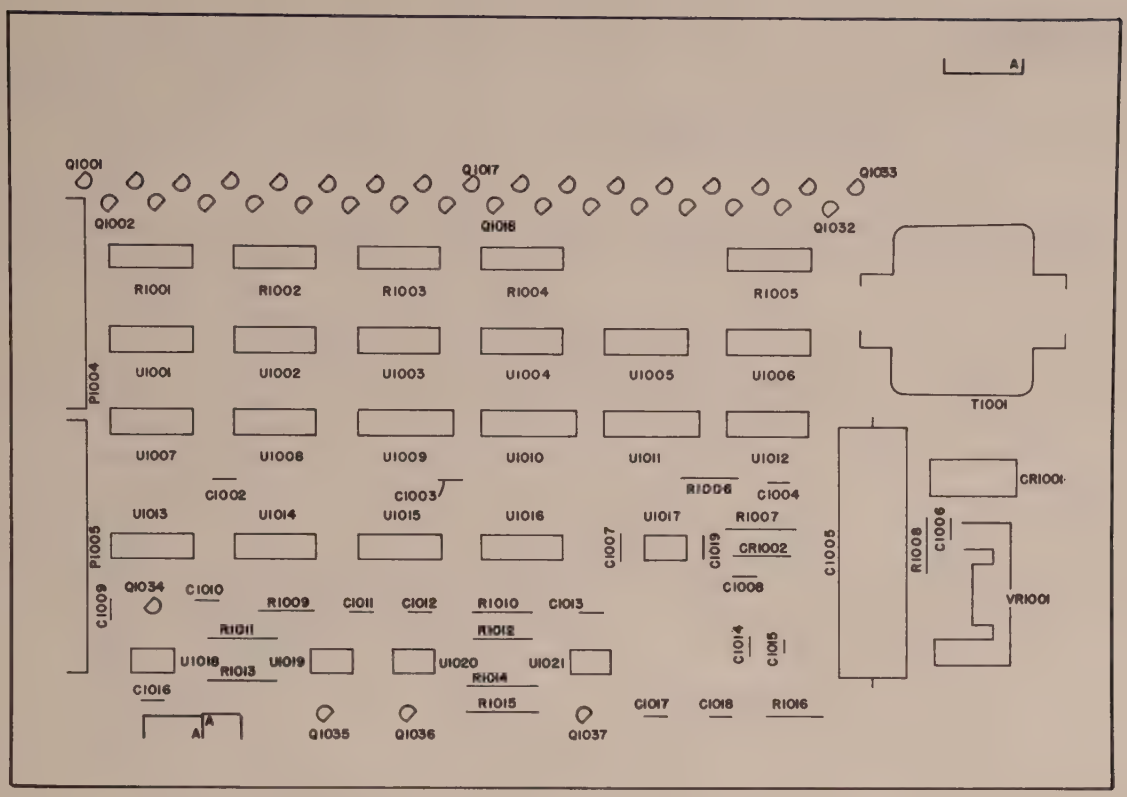
DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
XX ± .015 ANG ± 2°
XXX ± .005 FRAC ± 1/64
SURFACE MAX 63
DATE 4-2-75 SCALE ~
DRN R SMITH
MATERIAL
FINISH
TITLE SCHEMATIC, PC-404, BATTERY PACK
NO 26758C



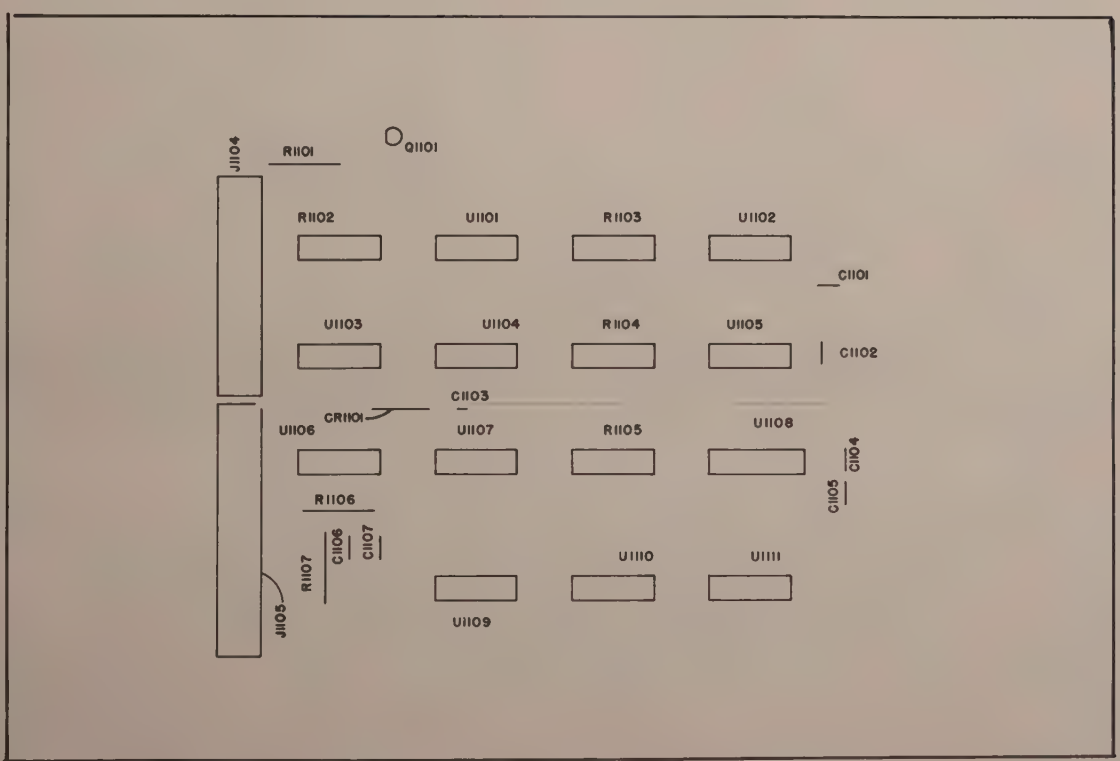
Component Layout, Option 06


27902E
J1001
J1003
T1001
CR1001
VR1001
P1005
P1006
P1004
J1002
U1017
THRESHOLD
UPTIME
UPDAT
UPCLK
DOWNCLR
FR
UPDATE
OVERFLOW STROBE
AUTOMODE STROBE
AUTORANGED
FLAG/FLAG STROBE
COMMON
GATECLK
DOWNDAT
OVERFLOW
AUTORANGED
AUTOMODE
VOLTS
AMPS
AC
OHMS
POLARITY
UNUSED GATES
MATES WITH J1004 (SEE PC-416 SCHEMATIC P/N 28019E)
PRINTER HOLD
RANGE STROBE
FUNCTION STROBE
POLARITY STROBE
PULL UP BUSS
SEE MAINFRAME SCHEMATIC
SEE NOTE 6
INCLK
SERDAT (SDAT)
SERCLK
RANGE
FUNCTION
NOTES
1. ALL RESISTOR VALUES ARE IN OHMS UNLESS MARKED OTHERWISE. (K-KILOHMS M-MEGOHMS)
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS MARKED OTHERWISE. (pF-PICOFARADS)
3. FLAGNOTES WITH SAME NUMBERS ARE CONNECTED.
4. DENOTES OPTIONAL CUSTOMER INSTALLED PULL-UP RESISTORS. (SEE INSTRUCTION MANUAL)
5. PULL-UP BUSS POWER SUPPLY JUMPER SELECTION - (SEE INSTRUCTION MANUAL)
6. CIRCUIT COMMON
7. DENOTES CHASSIS CONNECTION
HIGHEST SCHEMATIC DESIGNATIONS USED
SCHEMATIC DESIGNATIONS NOT USED
TITLE SCHEMATIC, PC-415, DIGITAL INTERFACE (BOTTOM)
DRAWN SMITH
DATE 10-22-75
SCALE
MATERIAL
FINISH
NO 27902E-


28019E
P1101
J1105
J1104
U1108
SHIFT REGISTER
PARALLEL SERIAL CONTROL
SERIAL INPUT
INTERCONNECTION SCREW TO PFT. SI SCHEMATIC NO. 27908E
MATES WITH P1004 (SEE PC-415 SCHEMATIC P/N 27902E)
NOTES:
1. ALL RESISTOR VALUES ARE IN OHMS UNLESS MARKED OTHERWISE. (K-KILOHMS M-MEGOHMS)
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS MARKED OTHERWISE. (pF-PICOFARADS)
3. DENOTES CHASSIS CONNECTION.
4. DENOTES COMMON.
5. DENOTES OPTIONAL CUSTOMER INSTALLED PULL-UP RESISTOR. (SEE INSTRUCTION MANUAL)
HIGHEST SCHEMATIC DESIGNATIONS USED
C107 CR1101 J1105
P1101 Q1101 R1107
U1111
SCHEMATIC DESIGNATIONS NOT USED
J1101 J1102 J1103
TITLE SCHEMATIC, PC-416, DIGITAL INTERFACE (UPPER)
NO 28019E



Component Layout, Option 51 , Lower Board (PC-415).



Component Layout, Option 51 , Upper Board (PC-416).

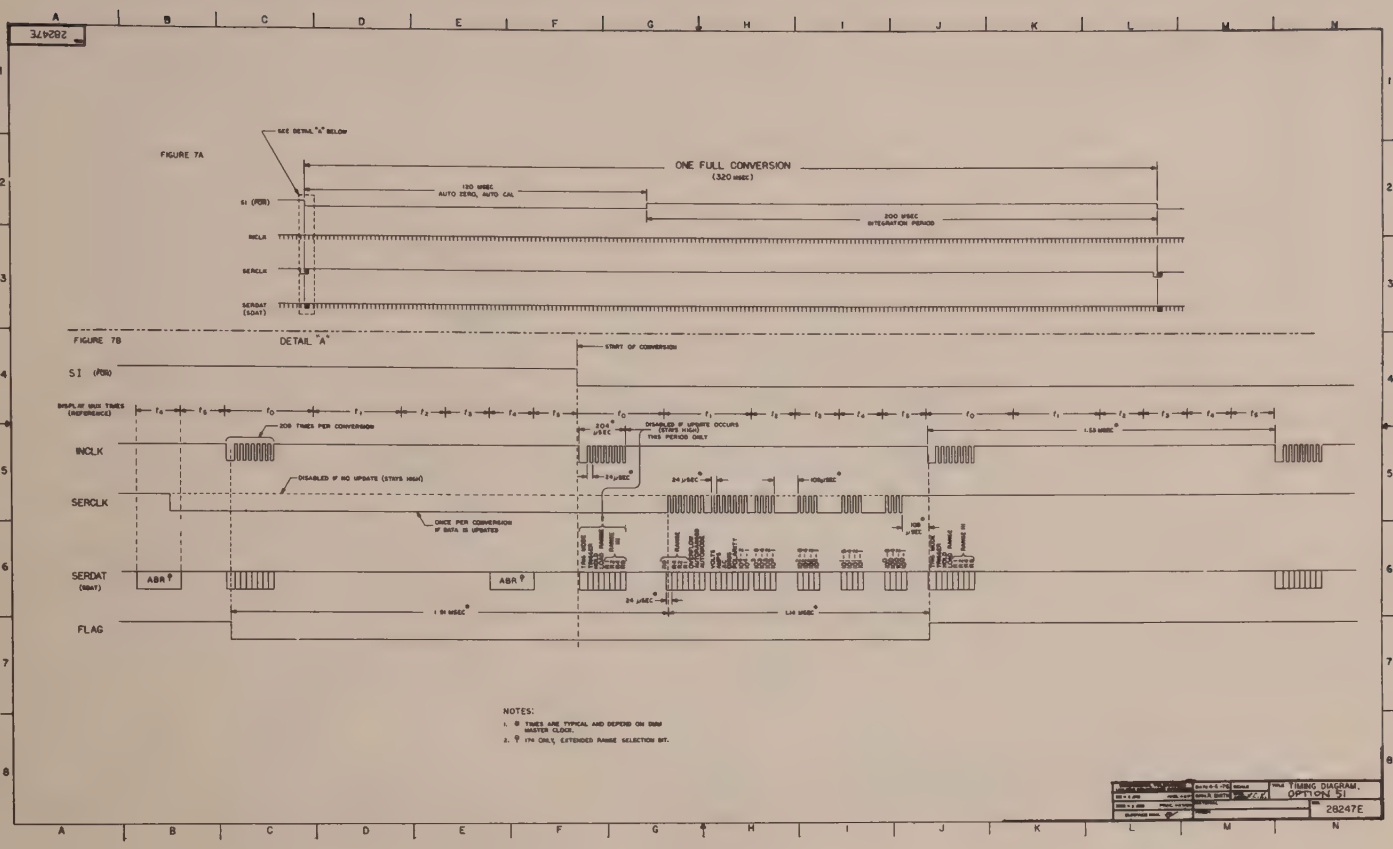
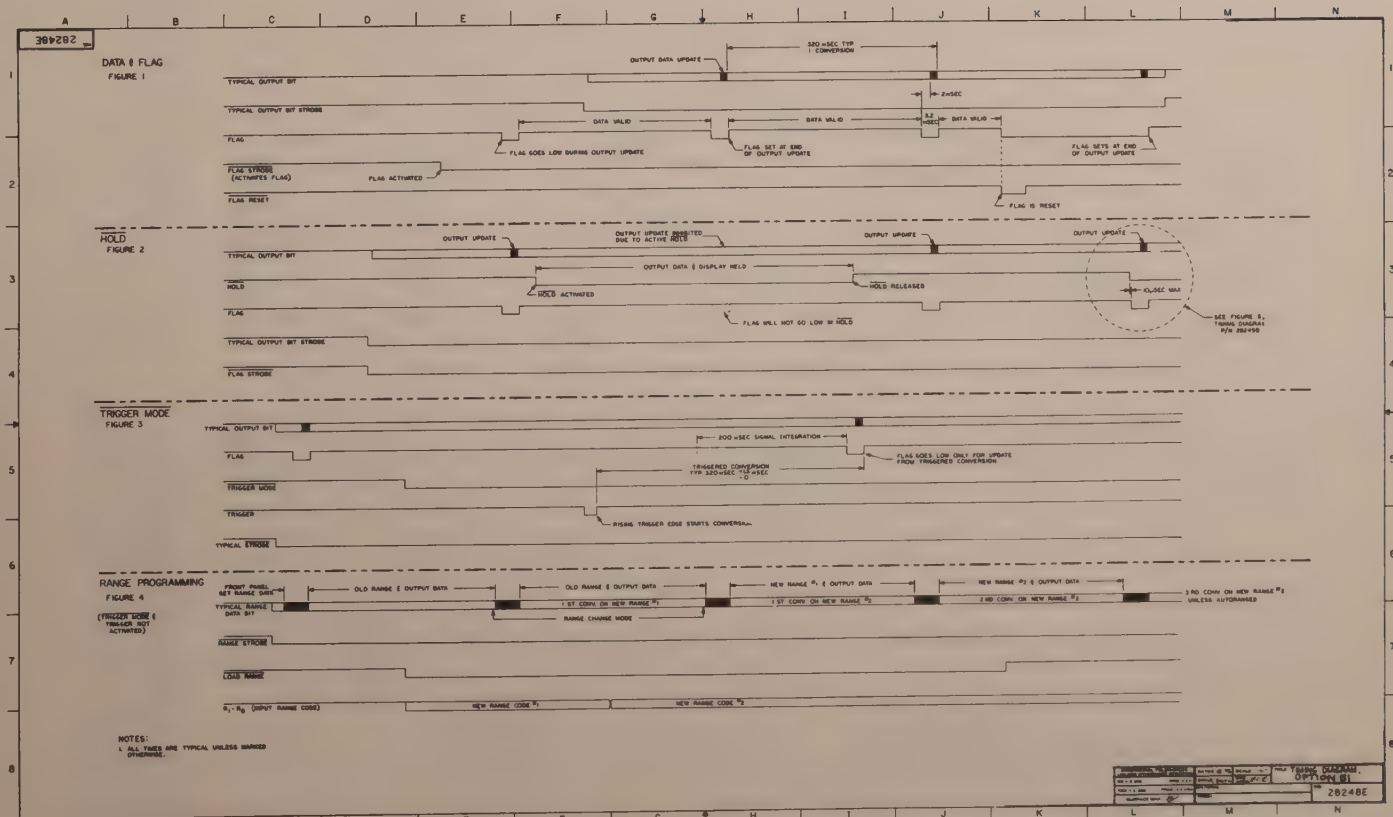


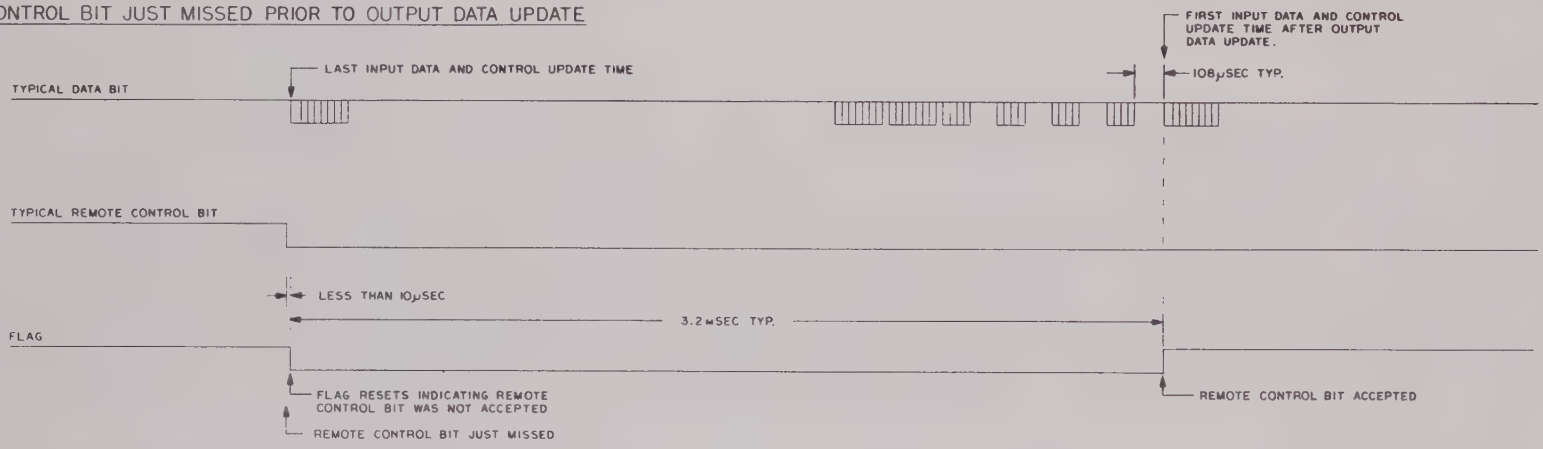
FIGURE 7A
SEE DETAIL "A" BELOW
ONE FULL CONVERSION
(320 MSEC)
130 MSEC
AUTO ZERO, AUTO CAL
200 MSEC
INTEGRATION PERIOD
SI (PDR)
INCLK
SERCLK
SERDAT
(SDAT)
FIGURE 7B
DETAIL "A"
START OF CONVERSION
DISPLAY SIGN TIMES
(REFERENCE)
208 TIMES PER CONVERSION
DISABLED IF NO UPDATE (STAYS HIGH)
ONCE PER CONVERSION
IF DATA IS UPDATED
DISABLED IF UPDATE OCCURS
(STAYS HIGH)
THIS PERIOD ONLY
ABR
FLAG
NOTES:
1. @ TIMES ARE TYPICAL AND DEPEND ON SUM MASTER CLOCK.
2. ♀ 17TH CHAR. EXTENDED RANGE SELECTION BIT.
TIMING DIAGRAM:
OPTION SI
28247E


DATA & FLAG
FIGURE 1
OUTPUT DATA UPDATE
320 MSEC TYP
1 CONVERSION
TYPICAL OUTPUT BIT
TYPICAL OUTPUT BIT STROBE
FLAG
FLAG STROBE
(ACTIVATES FLAG)
FLAG RESET
DATA VALID
FLAG GOES LOW DURING OUTPUT UPDATE
FLAG SET AT END
OF OUTPUT UPDATE
FLAG ACTIVATED
FLAG IS RESET
FLAG SETS AT END
OF OUTPUT UPDATE
HOLD
FIGURE 2
OUTPUT UPDATE
OUTPUT UPDATE PREVENTED
DUE TO ACTIVE HOLD
OUTPUT DATA & DISPLAY HELD
HOLD ACTIVATED
HOLD RELEASED
FLAG WILL NOT GO LOW IN HOLD
SEE FIGURE 8,
TIMING DIAGRAM
P/N 28249B
TRIGGER MODE
FIGURE 3
200 MSEC SIGNAL INTEGRATION
FLAG GOES LOW ONLY FOR UPDATE
FROM TRIGGERED CONVERSION
TRIGGERED CONVERSION
TYP 320 MSEC
TRIGGER MODE
TRIGGER
RISING TRIGGER EDGE STARTS CONVERSION
TYPICAL STROBE
RANGE PROGRAMMING
FIGURE 4
(TRIGGER MODE &
TRANSFER NOT
ACTIVATED)
FRONT PANEL
SET RANGE DATA
OLD RANGE & OUTPUT DATA
NEW RANGE #1 & OUTPUT DATA
NEW RANGE #2 & OUTPUT DATA
TYPICAL RANGE
DATA BIT
1 ST CONV ON NEW RANGE #1
1 ST CONV ON NEW RANGE #2
2 ND CONV ON NEW RANGE #2
UNLESS AUTORANGED
RANGE CHANGE MODE
RANGE STROBE
LOAD RANGE
R3 - R0 (INPUT RANGE CODE)
NEW RANGE CODE #1
NEW RANGE CODE #2
NOTES:
1. ALL TIMES ARE TYPICAL UNLESS MARKED OTHERWISE.
TIMING DIAGRAM:
OPTION SI
28248E

28249D

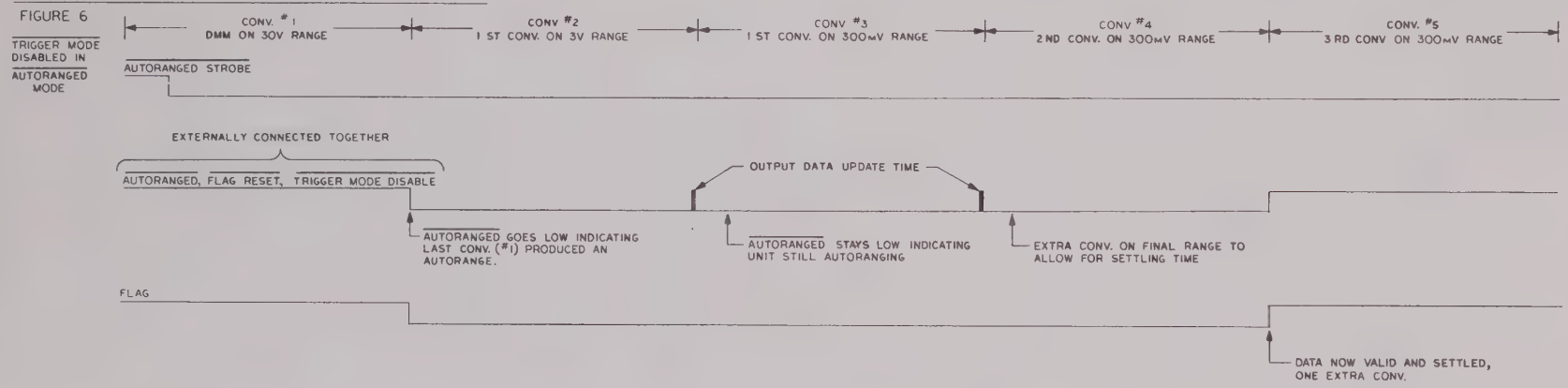
REMOTE CONTROL BIT JUST MISSED PRIOR TO OUTPUT DATA UPDATE

FIGURE 5


FIRST INPUT DATA AND CONTROL UPDATE TIME AFTER OUTPUT DATA UPDATE.
LAST INPUT DATA AND CONTROL UPDATE TIME
108μSEC TYP.
TYPICAL DATA BIT
TYPICAL REMOTE CONTROL BIT
LESS THAN 10μSEC
3.2 mSEC TYP.
FLAG
FLAG RESETS INDICATING REMOTE CONTROL BIT WAS NOT ACCEPTED
REMOTE CONTROL BIT JUST MISSED
REMOTE CONTROL BIT ACCEPTED

USE OF AUTORANGED AND TRIGGER MODE DISABLE

FIGURE 6


CONV. #1 DMM ON 30V RANGE
CONV #2 1 ST CONV. ON 3V RANGE
CONV #3 1 ST CONV. ON 300mV RANGE
CONV #4 2 ND CONV. ON 300mV RANGE
CONV. #5 3 RD CONV ON 300mV RANGE
TRIGGER MODE DISABLED IN AUTORANGED MODE
AUTORANGED STROBE
EXTERNALLY CONNECTED TOGETHER
AUTORANGED, FLAG RESET, TRIGGER MODE DISABLE
OUTPUT DATA UPDATE TIME
AUTORANGED GOES LOW INDICATING LAST CONV. (#1) PRODUCED AN AUTORANGE.
AUTORANGED STAYS LOW INDICATING UNIT STILL AUTORANGING
EXTRA CONV. ON FINAL RANGE TO ALLOW FOR SETTLING TIME
FLAG
DATA NOW VALID AND SETTLED, ONE EXTRA CONV.

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED	DATE 4-20-76	SCALE —	TITLE TIMING DIAGRAM
.XX ± .010 AND ± .01°	DRN R. SMITH	ENG APPR. R.C.K.	
.XXX ± .005 FRAC. ± 1/64	MATERIAL		NO 28249D
SURFACE MAX. 63	FINISH		

7-41/42

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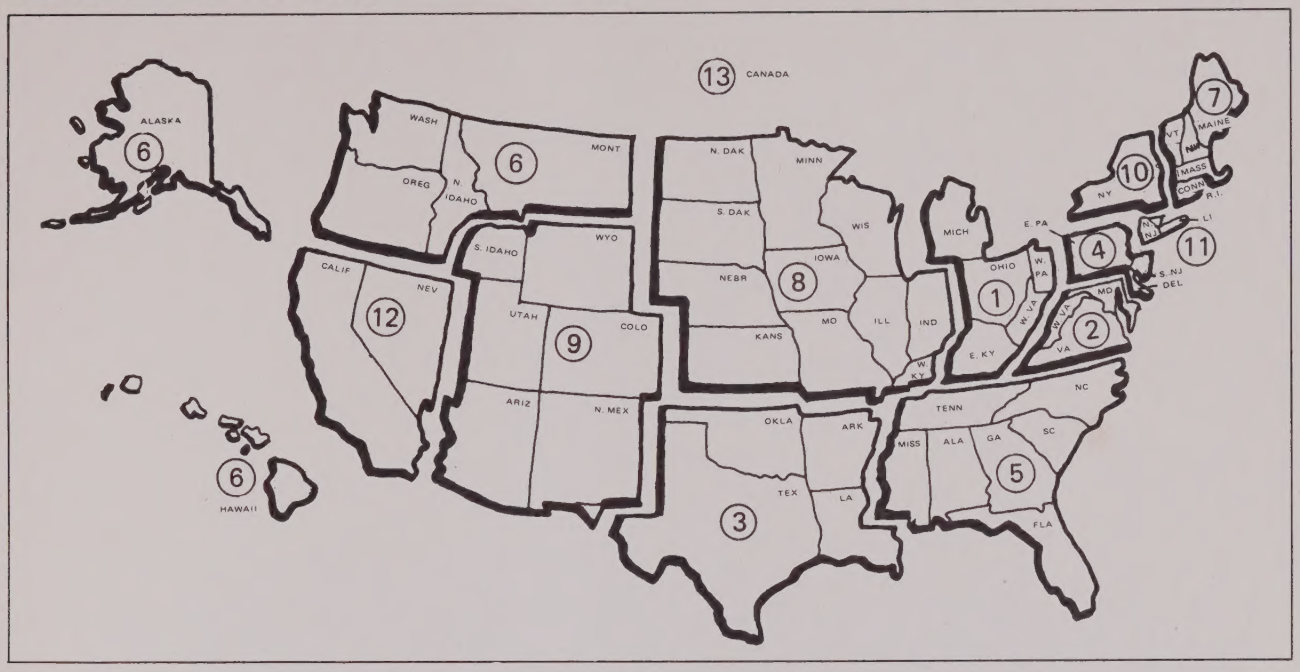
RACAL-DANA Instruments Inc.

U.S. REPRESENTATIVES



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